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THIRD UNITED NATIONS CONFERENCE ON THE EXPLORATION AND PEACEFUL USES OF OUTER SPACE

THE EARTH AND ITS ENVIRONMENT IN SPACE

Background paper 1

The full list of the background papers:

1. Earth and its environment in space
2. Disaster prediction, warning and mitigation
3. Management of Earth resources
4. Satellite navigation and location systems
5. Space communications and applications
6. Basic space science and microgravity research and their benefits
7. Commercial aspects of space exploration including spin-off benefits
8. Information systems for research and applications
9. Small satellite missions
10. Education and training in space science and technology
11. Economic and societal benefits
12. Promotion of international cooperation

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CONTENTS

		Paragraphs	*Page*
PREFACE			3
SUMMARY			4
I.	SOLAR-TERRESTRIAL RELATIONS	1-17	5
	A. Total solar irradiance and variations of its ultraviolet component	1-5	5
	B. Earth's magnetosphere, ionosphere and upper atmosphere	6-12	6
	C. Disturbances of the ionosphere and magnetosphere	13-17	7
II.	SPACE WEATHER EFFECTS ON THE EARTH'S ENVIRONMENT	18-36	8
	A. Effects on ground services	18-23	8
	B. Effects on humans and spacecraft	24-30	9
	C. Space weather forecasting: current situation and perspective	31-36	10
III.	GLOBAL CLIMATE CHANGE	37-46	11
IV.	OZONE DEPLETION	47-54	13
V.	TECHNOLOGY-INDUCED CHANGES IN THE GLOBAL ENVIRONMENT	55-65	15
VI.	WEATHER FORECASTING AND NATURAL DISASTER WARNINGS	66-74	17
VII.	SOCIAL AND ECONOMIC ASPECTS	75-80	18
VIII.	PROMOTION OF INTERNATIONAL COOPERATION IN THE EARTH SCIENCES	81-98	20
	A. International research programmes	81-82	20
	B. Coordination of operational and research satellite programmes and missions	83-91	20
	C. Participation of developing countries	92-98	22

PREFACE

The General Assembly, in its resolution 52/56, agreed that the Third United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE III) should be convened at the United Nations Office at Vienna from 19 to 30 July 1999 as a special session of the Committee on the Peaceful Uses of Outer Space, open to all Member States of the United Nations.

The primary objectives of UNISPACE III will be:

(a) To promote effective means of using space technology to assist in the solution of problems of regional or global significance;

(b) To strengthen the capabilities of Member States, in particular developing countries, to use the applications of space research for economic and cultural development;

Other objectives of UNISPACE III will be as follow:

(a) To provide developing countries with opportunities to define their needs for space applications for development purposes;

(b) To consider ways of expediting the use of space applications by Member States to promote sustainable development;

(c) To address the various issues related to education, training and technical assistance in space science and technology;

(d) To provide a valuable forum for a critical evaluation of space activities and to increase awareness among the general public regarding the benefits of space technology;

(e) To strengthen international cooperation in the development and use of space technology and applications.

As one of the preparatory activities for UNISPACE III, the Office for Outer Space Affairs of the Secretariat has prepared a number of background papers to provide Member States participating in the Conference as well as in the regional preparatory meetings, with information on the latest status and trends in the use of space-related technologies. The papers have been prepared on the basis of input provided by international organizations, space agencies and experts from all over the world. A set of 12 complementary background papers have been published and should be read collectively.

Member States, international organizations and space industry planning to attend UNISPACE III should consider the contents of the present paper, particularly in deciding on the composition of their delegation and in formulating contributions to the work of the Conference.

In the preparation of this background paper, contributions from the following organizations have been used: Centre national d'études spatiales, France; Department of Physics, Obafemi Awolowo University, Nigeria; European Space Agency, Paris Headquarters; Indian Space Research Organization, India; Institute of Theoretical Astrophysics, University of Oslo, Norway; National Institute of Aeronautics and Space, Indonesia; National Aeronautics and Space Administration, United States of America; National Space Development Agency of Japan; Solar Physics Subcommission of COSPAR; and the World Meteorological Organization.

The assistance of M. J. Rycroft (International Space University, Strasbourg, France and Cambridge University, United Kingdom of Great Britain and Northern Ireland) as technical editor of background papers 1-10 is gratefully acknowledged.

SUMMARY

The present background paper, entitled "The Earth and its environment in space", reviews the status of scientific knowledge of the Earth and its environment, including the influence of solar activity on the magnetosphere, ionosphere and upper, middle and lower atmosphere, climate change, ozone depletion and atmospheric pollution by natural and anthropogenic factors. The state of international cooperation in the environmental sciences at the global, regional and local levels, as well as the participation of developing countries, is discussed.

In the next century, the planet Earth faces the potential hazard of rapid environmental changes, including global warming, rising mean sea level, deforestation, desertification and land degradation, ozone depletion, acid rain and a reduction in biodiversity. Such changes will have a profound impact on all countries, yet many important scientific questions remain unanswered. Scientific research shows that the Earth has changed over time and continues to change. Human activity has altered the condition of the Earth by reconfiguring the landscape, by changing the composition of the global atmosphere and by stressing the biosphere in countless ways. There are strong indications that natural change is being accelerated by human intervention. In its quest for improved quality of life, humanity has become a force for change on the planet, building upon, reshaping and modifying nature, often in unintended and unpredictable ways.

There are, however, many uncertainties in climate models, among which are the lack of understanding of clouds and aerosol effects on climate and the role of oceans in global climate change. Thus, observing these parameters from space, as well as the monitoring of greenhouse gases are most important. The depletion of stratospheric ozone is now evident all over the world except in the tropics, with the Antarctic ozone hole as its most conspicuous manifestation. Satellite observations have demonstrated their usefulness in monitoring ozone globally and in observing the global distribution of stratospheric trace species involved in ozone chemistry. However, measurements of ozone altitude profiles should be improved in terms of accuracy, frequency and horizontal resolution.

The variation of solar irradiance is partially responsible for climate change, and the variation of solar ultraviolet irradiance affects photochemical reactions in the upper atmosphere. In order to determine the solar influence on Earth, it is essential to monitor total and spectral solar irradiance, coronal mass ejections and other attributes of solar activity fluctuations, solar wind and energetic particles, and the structure and dynamics of the lower, middle and upper atmosphere. In order to understand the global behaviour of solar-terrestrial interactions, the magnetosphere, ionosphere and upper atmosphere should be viewed as a complex system.

The observational requirements arising from the need to understand more fully the Earth system and to provide services based on that increased understanding are wide-ranging and involve many different measuring techniques and associated data-processing systems. Satellites located in a variety of orbits provide critical and unique global observational platforms from which to monitor the Earth system comprehensively. Data obtained from space are voluminous, and special efforts need to be made to establish an international system in order to appropriately process, archive and freely disseminate them.

Instruments aboard satellites provide the unique ability to make observations and monitor processes on a global basis. Indeed, they provide the only means by which several critical parameters can be studied. They also provide the information necessary to model the Earth system and to make forecasts of short-term and long-term changes of social and economic importance. However, comprehensive ground-based observing systems are also necessary to complement space-based observational systems. In order to harmonize all international efforts in the field of environmental monitoring, it is necessary to establish an integrated global observation and monitoring system.

Moreover, there is a substantive need to build an infrastructure in developing countries so that they can apply the analysis of current and future observations, the results of research and the results of model output (including predictions) towards better management of resources and as a basis for policy decisions regarding the environment as well as socio-economic activity. Some of the knowledge can be directly used for decreasing the impact of natural hazards, e.g. to monitor and mitigate large-scale wild fires, floods or droughts. Over a longer time scale, this knowledge will lead to more reliable weather and climate predictions. Only by systematically monitoring synoptic data and by making research observations can scientists further their knowledge of the global environment and its variations, so that humankind can better adapt to natural changes and minimize those induced by technology.

It has become abundantly clear that improved scientific understanding, observations and research are required to provide the basis for informal and formal policy decisions regarding environmental issues that lead to a host of resource management, social, health and economic development consequences. These issues are equally important at national, intergovernmental or international levels. No single country or region can undertake the cost or responsibility for the implementation of observational, research and development programmes and projects; associated global services to adequately address the needs of sustainable development are needed.

I. SOLAR-TERRESTRIAL RELATIONS

A. Total solar irradiance and variations of its ultraviolet component

1. The Sun is the primary driver and energy source for atmospheric and ocean circulation systems and the climate at the Earth's surface. At the surface of the Earth, the combination of available solar energy, water and soil nutrients determines to a large extent the plant and animal life possible at any one location (see section III). Solar electromagnetic radiation varies much less at visible and infrared wavelengths than at short (ultra-violet (UV) and X-ray) and radio wavelengths.

2. UV irradiance is a major energy source for the Earth's atmosphere, and small fluctuations in atmospheric parameters (e.g. small changes in total ozone amount) can produce dramatic differences in the solar radiation reaching the Earth's surface. Increasing UV irradiance is known to cause increases in the occurrence of skin cancer and also can affect micro-biological systems by damaging or altering their genetic structure. Measuring small changes in solar UV irradiance will improve the understanding of corresponding changes in the photochemistry, dynamics and energy balance of the middle atmosphere. Variations in short wavelength (UV and X-ray) solar spectral irradiance are much larger than the variations in total solar irradiance. They affect the temperature and chemistry (e.g. ozone, nitric oxide) in the middle and upper atmosphere. Changes in thermospheric circulation alter the electrodynamic structure of the upper atmosphere and, through dynamo action, magnetosphere-ionosphere coupling processes.

3. Cosmogenic isotope records show a 200-year cycle of solar activity and total solar luminosity. There is a possible correlation between shorter time scales of 10 to 30 years, and long-term periodic tendencies towards droughts in some regions of the world. Sunspot cycle length and global average temperature anomalies at the Earth's surface show a high correlation (0.95) over the past 100 years. At present, there is considerable discussion about the reasons for such a high correlation with solar activity fluctuations which, according to satellite observations, appear to be linked with only small changes in total solar irradiation. Probably the greatest correlation between sunspot activity and the Earth's climate occurred between 1640 and 1720, when solar activity in the form of sunspots declined and temperatures in northern Europe fell by about one degree Celsius (C), the period is sometimes called the "Little Ice Age".

4. The only means to measure total solar irradiance outside the Earth's atmosphere is to use instruments on satellites. Such instruments have been available only since 1978, a time interval that is too short for a serious study of the Sun's long-term behaviour. However, there is evidence that long-term variations could be large and as yet undetected by direct satellite measurements. Of recent scientific interest is the fact that the luminosity of the Sun appears to have changed between the minima of solar cycles 21 and 22 by an amount that could, if maintained, produce a 0.5 to 1.0 per cent luminosity change on the cosmogenic time scale required to drive climate events such as the Little Ice Age. Satellite data show that total solar irradiance reached a low point in 1986, near the minimum of the 11-year solar cycle, climbed to a peak in about 1991, and then declined to another low in 1996.

5. Important scientific issues and objectives include:

(a) Continuing observations and long-term monitoring of solar spectral irradiance;

(b) Modelling solar activity and its fluctuations;

(c) Assessing the interaction between fluctuations in solar radiation and the Earth's climate;

(d) Quantifying through observations and models solar influences on both short-term (weather to seasonal and inter-annual time scales) and long-term (10 to 30 year or decadal) climate variability and change.

B. Earth's magnetosphere, ionosphere and upper atmosphere

6. The response of the global environment to the constantly changing Sun is currently known as "space weather". The impact of solar disturbances on the Earth, however, had been recognized long ago. The solar origin of geomagnetic storms, rapid and irregular fluctuations of the geomagnetic field, which are more intense in the polar regions, and aurorae, which are excited by the entry into the atmosphere of charged particles, were identified even before the space age. It was only during the space age that such phenomena and their disruptive effects on electrical and telecommunications systems came to be better understood.

7. The Sun and its atmosphere are always changing, in a sense having "weather" of their own. The Sun undergoes long-term (10 years or more) "climate-like" variations such as the roughly 11-year solar cycle. This cycle first showed itself in the number of sunspots (dark concentrations of intense magnetic fields emerging from below the Sun's surface) counted on the solar surface as observed by a telescope on the ground. The numbers of sunspots appearing on the solar surface were soon observed to vary with time in an approximately 11-year cycle. This regular increase and decrease in the level of solar activity is called the solar cycle.

8. Although sunspots themselves produce only minor effects on solar emissions, the magnetic activity that accompanies them can produce dramatic changes in ultraviolet and soft X-ray emission levels. Recent space observations have revealed that complexes of sunspots called active regions are the main source of long-lived solar features with enhanced ultraviolet and X-ray emissions. Solar gas, confined by strong active-region magnetic fields into loop-like structures, is heated to temperatures of several million degrees. During times of maximum solar activity, the average level of solar ultraviolet emission can increase to several times the quiet Sun level, while the X-ray intensity shows even greater enhancements. Since active regions usually last longer than the 27-day solar rotation period, the radiation which they emit also vary periodically on this time scale.

9. The Sun appears completely different in an X-ray than in the sky. X-rays are emitted by very hot gases in the outer solar atmosphere, the corona, where the temperature reaches a few million degrees; the much cooler surface of the Sun, at 6,000 degrees, is not hot enough to emit X-rays. As a result, an X-ray image reveals a bright glow for the corona and a black disk for the surface of the Sun. In the corona, the shape and character of

the hot gases are controlled by magnetic fields, just as beads move along the string on which they are threaded. As the solar activity cycle progresses from maximum to minimum, the Sun's magnetic field changes from a complex structure to a simpler configuration. Since the Sun's hot gases are controlled by the magnetic field, X-ray images reflect this global change, with an overall decrease in brightness by 100 times.

10. The high temperature of the solar upper atmosphere generates an outward flow of ionized coronal gas or plasma away from the Sun at typical speeds ranging from 400 to 800 kilometres per second. This outflow is known as the "solar wind". The solar wind flows around obstacles such as planets, but planets with their own magnetic fields respond in specific ways. Under the influence of the solar wind, a planet's magnetic field lines are compressed in a sunward direction and stretched out in a downwind direction. This creates a magnetosphere, a complex, tear drop-shaped cavity around a planet that possesses a magnetic field, such as the Earth. The Van Allen radiation belts are within this cavity, as is the ionosphere, a layer of Earth's upper atmosphere where photoionization by solar X-rays and extreme ultraviolet rays creates free electrons and ions.

11. The geomagnetic field senses the solar wind and its speed, density and magnetic field. Because the solar wind varies over time scales as short as seconds, the interface that separates interplanetary space from the magnetosphere is very dynamic. Normally this interface, called the "magnetopause", lies at a distance equivalent to about 10 Earth radii in the direction of the Sun. However, during episodes of elevated solar wind density or velocity, the magnetopause can be pushed inward to within 6.6 Earth radii (the altitude of geosynchronous satellites). As the magnetosphere extracts energy from the solar wind, its form and structure depends on solar activity, and complex effects, not yet completely understood, are observed.

12. The aurora is a dynamic and delicate visual manifestation of solar-induced geomagnetic activity. Solar wind particles entering the magnetosphere also energize electrons and ions that are trapped there. Particles with sufficient energy can enter the Earth's upper atmosphere, usually near the polar regions. When the particles strike the molecules and atoms of the thin, high atmosphere, some of them start to glow in different colours. During periods of high geomagnetic activity, the regions to which energetic particles penetrate may extend to much lower latitudes. In such cases, aurorae and other geomagnetic disturbances, which could negatively influence human activities, can be observed much farther from the poles than usual (see section II.B).

C. Disturbances of the ionosphere and magnetosphere

13. There are two different types of events on the Sun that trigger disturbances in the Earth's environment. One type is called a "solar flare" because the brightening of a small area on the Sun heralds its occurrence. The other type is called a "coronal mass ejection" (CME) and is, in fact, a huge eruption of material from the solar atmosphere into interplanetary space. Flares and CMEs are not unrelated, but most flares are not accompanied by a CME, and many CMEs occur without a visible flare.

14. When a flare occurs on the Sun, a large increase in electromagnetic radiation follows (mainly photons with energies in the extreme ultraviolet (EUV) and X-ray portion of the energy spectrum). The energetic electromagnetic radiation bursts accompanying flares on the Sun travel at the speed of light and thus arrive at Earth just eight minutes after leaving the flare site, well ahead of any charged particles or coronal material associated with the flare. The direct response of the upper atmosphere to a burst of solar flare ultraviolet and X-ray emissions is a temporary increase in ionization (as well as temperature) in the sunlit hemisphere. The phenomenon, which can vary from a few minutes to hours, is called a "sudden ionospheric disturbance" (SID). The increase of ionization at altitudes below 100 kilometres is especially significant on such occasions.

15. While solar flares affect the ionosphere, CMEs occur when the magnetosphere is disturbed by plasma that propagates through interplanetary space to the Earth after sudden disruptions in the solar magnetic field. A large CME can contain a billion tons of matter that can reach speeds up to 2,000 kilometres per second, considerably

greater than normal solar wind speeds of about 400 kilometres per second. Thus, unlike solar flares, which emit enhanced EUV/X-ray radiation, CMEs result in a "cloud" of charged particles (ions and electrons). This cloud often brings with it parts of the solar magnetic field and is often named a "magnetic cloud". The charged particles and the magnetic field will interact with the Earth's magnetic field when the cloud reaches the Earth's orbit, causing a geomagnetic storm.

16. Geomagnetic activity in the Earth's environment can also be caused by solar wind fluctuations that are due to large-scale structuring of the solar surface. The main source of solar wind is from so-called coronal holes. These are regions of the solar corona where the density is lower than average and the temperature and associated solar wind expansion velocity are higher than average. Their name reflects the fact that they appear dark in X-ray images of the corona owing to their low density. Coronal holes are mostly restricted to the polar regions (called "polar coronal ho :s") but can sometimes extend to lower latitudes, down towards the Sun's equator. When, during the rotatio of the Sun, a boundary between the fast solar wind coming from the holes and slow solar wind crosses the Earth, geomagnetic activity is also often enhanced. Because coronal holes are long-lived structures, such disturbances may repeat themselves with the 27-day solar rotation period.

17. Important scientific issues and objectives include:

(a) Investigating solar system plasmas and the current systems and magnetic fields associated with them;

(b) Improving the observation and understanding of the physical processes governing the Earth's thermosphere, magnetosphere, ionosphere and upper atmosphere;

(c) Developing a detailed, theoretically based understanding of the physical processes that constitute the Sun-Earth connection, improving the prediction of geo-effective solar activity and forecasting space weather conditions;

(d) Improving the observations and understanding of solar variability and the mechanisms by which the energy generated in the Sun's core is released into space;

(e) Characterizing the dynamics, properties and structure of the solar wind as it blows through interplanetary space and interacts with local interstellar medium to form the heliosphere.

II. SPACE WEATHER EFFECTS ON THE EARTH'S ENVIRONMENT

A. Effects on ground services

18. Short-wave radio communications at HF frequencies (3-30 MHz), which are still extensively used for long-distance telecommunications services in various countries, depend upon the reflection of signals from the Earth's ionosphere. The effects of an SID are an increase in the local electron concentration in the ionosphere, which can cause a total radiocommunication blackout. These increases are caused by solar flare short-wave radiation, but an inflow of energetic particles from a flare and geomagnetic storms also cause disturbances in the ionosphere. The ionospheric changes that occur during disturbed times also increase the incidence of electron density irregularities, leading sometimes to severe variations in the phase and strength of signals sent from the ground to satellites at VHF and UHF frequencies (30 MHz to 3 GHz).

19. Geomagnetic surveys are important tools in the commercial exploration of natural resources, such as the search for oil and gas. However, space weather-related perturbations can create signals in survey data that can

be mistaken for signatures of sub-surface resources. Survey schedules or operations must be modified, often suddenly and with significant cost impacts, to avoid contamination of the survey data.

20. Navigation systems such as LORAN and OMEGA are adversely affected when solar activity disrupts their radio wavelengths. The OMEGA system consists of eight transmitters located throughout the world. Aeroplanes and ships use the very low frequency radio signals from these transmitters to determine their positions. During solar events and geomagnetic storms, the system can give navigators information that is inaccurate by as much as several miles. If navigators are alerted that a solar flare event or geomagnetic storm is in progress, they can switch to a backup system.

21. The same disturbance-related changes in the Earth's ionosphere that affect communications introduce changes in the time it takes signals to traverse the ionosphere. The abnormal time delays introduce position errors and decrease the accuracy and reliability of the satellite-based Global Positioning System (GPS), which is used for many range-finding and navigational purposes.

22. Electric power systems on the ground can be affected by the enhanced currents that flow in the magnetosphere-ionosphere system during geomagnetic disturbances. Such disturbances can induce almost direct currents (geomagnetically induced currents (GIC)) in long power lines. For instance, during the 13 March 1989 magnetic storm, GIC caused a complete shutdown of the Hydro-Quebec power grid, resulting in a nine-hour power outage. The power pools that served the entire northeastern United States of America came uncomfortably close to a cascading system collapse.

23. Space weather-induced currents similarly flow in long conductors on the ground such as oil pipelines. These currents create galvanic effects that lead to rapid corrosion at the pipeline joints if they are not properly grounded. Such corrosion requires expensive repairs or can lead to permanent damage.

B. Effects on humans and spacecraft

24. While the damaging effects of radiation and energetic charged particles coming from solar flares have been known for a long time, some of the aspects of solar coronal mass ejections on Earth and artificial spacecraft, such as the impact on communications satellites, have become evident only recently through investigations performed within the international solar terrestrial physics (ISTP) space programme. A reliable prediction of the extent of the Earth-directed CMEs, as well as the probability of the occurrence of flares from which energetic particles can be magnetically guided to Earth, would make it possible to issue alerts to avoid major hazards to astronauts as well as to communications satellites (which can either be temporarily switched off or designed to enter a safe-mode when a cloud of solar plasma reaches the Earth's environment).

25. The upper atmosphere becomes inflated if it is heated by extra energy sources such as auroral charged particles and enhanced resistive ionospheric currents. The resulting increased atmospheric densities at altitudes of 300-500 kilometres significantly increase the number of collisions between satellites and surrounding gas particles. This "increased satellite drag" can alter an orbit enough so that a satellite is temporarily lost to communications links. At times, these effects may be sufficiently severe as to cause the premature re-entry of orbiting objects, such as Skylab in 1979 and the Solar Maximum Mission in 1989.

26. Energetically charged particles that originate from the Sun and from the Earth's magnetosphere impact the surfaces of spacecraft. Highly energetic particles can penetrate into electronic components, causing bit-flips, or errors, in a chain of electronic signals, which can result in spurious, or phantom, commands that appear to spacecraft systems to be directions from the ground. In addition, on-board instruments may generate erroneous data. These spurious commands have caused major failures in satellite systems and have even caused spacecraft to point away from the Earth and lose radio contact.

27. Many failures could probably have been avoided had ground controllers known in advance of impending charged particle hazards. During large solar storms, satellite operators may not even be aware of satellite anomalies because their communications links to the satellites are inoperable due to the geomagnetic storm itself. Less energetically charged particles contribute to a variety of spacecraft surface charging problems, especially during periods of high geomagnetic activity. In addition, energetic electrons responsible for deep dielectric charging can degrade the useful lifetime of internal components.

28. Data on spacecraft anomalies are maintained by the National Oceanic and Atmospheric Administration (NOAA) at its National Geophysical Data Centre (NGDC) at Boulder, Colorado. However, it is often difficult to obtain information on satellite anomalies since many satellite operators are not willing to share such information. For a period of 25 days in March 1989, in connection with a severe magnetic storm, 46 instances of operational disturbances were reported; the majority were diagnosed to be due to electrostatic discharges resulting from spacecraft charging. Such failures occurred in the Japanese geostationary telecommunications satellite CS-3B in 1989 and the Canadian Anik satellite in January 1994. An Earth-directed coronal mass ejection led to the failure of the Telstar 401 communication satellite in January 1997.

29. Energetic solar protons are a radiation hazard to astronauts on manned space flights. The arrival time in the near-Earth environment can begin within some tens of minutes of the eruption of a solar flare. While low inclination orbits take advantage of the shielding of the Earth's magnetic field, high inclination orbits place a spacecraft outside normal rigidity cut-offs, causing increased dosages. The International Space Station will use a high inclination orbit of about 52 degrees. The prediction and monitoring of solar flares and CMEs should provide essential safety constraints.

30. Radiation exposure to passengers in high-altitude aircraft and, in particular, to crew members who repeatedly make such flights is also of concern. Although the residual atmosphere above an aircraft provides a measure of protection from cosmic rays and solar energetic particles that enter the magnetosphere, there is still concern about flights on polar routes during major solar charged particle events. Radiation sensors on Concorde supersonic jets have shown that passengers and crew sometimes receive a radiation dose equivalent to a chest X-ray. To reduce the risk to aircraft crews and passengers, routine forecasts and alerts are sent through appropriate channels so that a flight in potential danger can consider what course of action to take to minimize radiation exposure.

C. Space weather forecasting: current situation and perspective

31. Space weather forecasting is based on observations of the Sun, from both the ground and space. In addition, several satellites monitor the Earth's environment by measuring key physical parameters. Images of the Sun in various spectral regions and selected spectral lines give information about the occurrence of flares and, together with magnetic field measurements (solar magnetograms), about the probability of flare occurrence in the future. This involves a great uncertainty, since it is not possible to follow the development of active regions on the invisible hemisphere of the Sun. Some types of configurations of the magnetic field of active solar regions have a greater possibility of creating a flare than others. However, it is impossible to predict the time when a flare might occur. Space-borne detectors also monitor the radiative output from the Sun. In particular, the Geostationary Operational Environmental Satellite (GOES) series provide measurements of the solar X-ray flux. A few minutes after a flare occurs, even if ground-based observatories miss the flare owing to night time or bad weather, the enhanced X-ray flux from the Sun gives the first indication of the strength of the flare.

32. Even when solar active phenomena are observed, either by ground-based observatories or by satellites, it is very hard to estimate the expected effects on the Earth's environment. Flares are sources of X-rays and energetic charged particles but are only loosely associated with geomagnetic storms. Real time observations of

CMEs are a much better tool for monitoring space weather but, even if a CME that is moving towards the Earth is discovered, the enormous distance between the Sun and the Earth leads to large uncertainty in an advance forecast for two reasons. First, the strength and velocity of the particle/magnetic cloud are very difficult to determine accurately based on CME observations. Secondly, the characteristics and the structural dynamics of the particle cloud as it crosses interplanetary space are poorly understood and can only be re-examined once it arrives at satellites near the Earth.

33. A key to accurate, short-term forecasting of new disturbances is a continuous, real-time solar wind observation. Data obtained at libration point L1 (240 Earth radii upstream), where the Earth's gravitational pull is balanced by that of the Sun, provide a 30 to 50 minute warning of when a shock or disturbance in the solar wind will encounter the Earth's magnetosphere. The precise time depends on the solar wind velocity, which can be measured by an instrument aboard a satellite near the libration point L1, which is well outside the influence of the geomagnetic field. Because such satellites are continuously in daylight, they can observe the Sun and the solar wind 24 hours a day, while all previous solar observatories had a low Earth orbit, and their observations were periodically interrupted because of the Earth's shadow.

34. The first two solar wind monitoring satellites at the libration point (Solar and Heliospheric Observatory (SOHO), since 1995, and Advanced Composition Explorer (ACE), since 1997) will improve the accuracy of space weather forecasts. In addition, they will improve knowledge about the mechanisms that produce solar storms (both flares and CMEs) and how a magnetic shock front travels through interplanetary space before it hits the Earth's environment to create a geomagnetic storm.

35. Some 20 satellites orbiting around the Earth in low orbits or eccentric orbits, or near the libration point, as well as 30 ground-based observatories around the globe, are used by scientists from a dozen countries to monitor the geomagnetic events in the frame of the international solar-terrestrial physics (ISTP) programme. This complex programme has been demonstrating the value of international cooperation and should eventually lead to more accurate forecasts of space weather, both in the short term to issue alerts and in the long term by building a sufficient database to develop better models of solar activity level variations.

36. The last solar minimum was reached in late 1996, and solar cycle No. 23 started in 1997. An increasing number of active regions from the new cycle have begun to appear, and the number of flares and CMEs will continue to increase in the next few years, as will the strength of the events. It is important for society to be more sensitive to space weather activity now and during the upcoming solar maximum in 2000-2003.

III. GLOBAL CLIMATE CHANGE

37. The possibility of unprecedented global climate change largely driven by human activity is a subject of considerable international concern. This concern has been expressed through the United Nations Framework Convention on Climate Change (A/AC.237/18 (Part II)/Add.1 and Corr.1, annex I). The Intergovernmental Panel on Climate Change (IPCC), which was jointly established by the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) in 1988, has issued periodic scientific assessments of global climate change and its possible impact for the past several years. Model simulations and retrospective predictions correspond to the "observed" global change in temperature of about 0.5 degrees C of warming over the past 100 years, attributed (at least in part) to increasing concentrations of greenhouse gases and amplified by feedback through increasing water vapour etc. IPCC has estimated that global surface air temperatures will increase significantly in the next 100 years. The likely consequences of this warming include changing patterns of temperature and precipitation (rainfall), increased sea-level rise and altered distribution of freshwater supplies. The impact on human health, the vitality of forests and other natural areas, and the productivity of agriculture are all likely to be significant.

38. The global climate at any point in time is a consequence of complex interactions between the solar energy input to the Earth, the atmosphere and atmospheric composition, the oceans (including the mid- and deep-ocean circulation), the hydrological cycle (which includes rivers, lakes, clouds/precipitation processes etc.), the land surface and vegetation/biosphere, the cryosphere (snow and ice fields, ice sheets and glaciers) and the geosphere (continental topography and tectonic changes, volcanic eruptions, Earth rotation etc.). In recent years, two other components were added, namely the chemosphere (various chemical species that are injected into the atmosphere) and the technosphere (i.e. changes in the land surface, the atmosphere, the oceans etc. introduced by current technology and/or social and cultural practices).

39. The global climate will always change. However, the fact that increasing human activity is causing climate change at a much more rapid rate than before is a cause for concern. There may be too little time for adaptation through natural processes such as plant "migration". Even with technology, very long lead times are necessary to accommodate and compensate for the possible impacts of global climate change.

40. The Earth system has gone through very cold and warm periods before. The reasons for past changes were probably the changes of the Earth's orbit around the Sun, fluctuations of solar irradiance, volcanic eruptions and other natural phenomena. Paleoclimatic records in air bubbles trapped in Antarctic ice cores indicate that the concentrations of carbon dioxide (CO_2) and methane (CH_4) show a high correlation with local temperature changes over the past 220 thousand years, even though the timing precision of the analysis precludes an exact determination of which variable leads the other.

41. Recent climate history indicates that there has been a global warming of about 0.5 degrees over the past 100 years. which is generally attributed to increasing concentrations of greenhouse gases CO_2 is injected into the atmosphere during the burning of fossil fuels, methane is emitted by expanding for example rice fields and livestock, and oxides of nitrogen are generated during fossil fuel burning and possibly from fertilizers used in agriculture. Other greenhouse gases are technologically produced molecules called chlorofluorocarbons (CFCs), whose use in air conditioning has been prohibited. The greenhouse warming effect of one molecule of some CFCs is equivalent to about 10,000 molecules of CO_2. CFCs also deplete the ozone layer, thereby permitting increased UV-B radiation to penetrate the atmosphere to the Earth's surface. They are, therefore, doubly dangerous.

42. Computations show that the Earth's average surface temperature of +15° C would be -18° C were it not for the presence of greenhouse gases. The notion of an "enhanced greenhouse effect" refers primarily to the incremental global warming caused by increasing concentrations of anthropogenically introduced "infrared active" greenhouse gases over and above the greenhouse effect caused by naturally occurring greenhouse gases (e.g. water vapour). During the twentieth century, the combustion of fossil fuels and industrial activity have disturbed the equilibrium that has kept the Earth's average temperature at +15° C. The CO_2 levels in the atmosphere have increased from 280 parts per million (ppm) by volume in 1860 to about 360 ppm in 1995. The increased amounts of CO_2 and other greenhouse gases have absorbed more and more infrared radiation, which has contributed to the temperature rise of 0.5 +/- 0.1° C since the nineteenth century. With increasing temperatures and therefore hotter summers and milder winters, glaciers have begun to melt and have led to a rise in the sea level.

43. The understanding of enhanced global warming is complicated by the fact that there are also many natural phenomena causing variability in the climate on inter-annual and inter-seasonal time scales. Examples are the El Niño and the Southern Oscillation (ENSO), periodic variations in rainfall that occurs in the Sahel and in northeastern Brazil, the inter-annual variability of monsoons, Quasi-Biennial Oscillation (QBO) and the decadal and inter-decadal interactions between the atmosphere and ocean.

44. Ongoing satellite missions make, or help derive, key global observations from geostationary and polar orbiting platforms of: atmospheric structure and dynamics (e.g. temperature, water vapour fields, precipitated water, clouds, winds); sea surface temperature; directly measured and derived surface characteristics (e.g. sea level, sea state, sea ice, snow cover, flooding, vegetation index, precipitation amount); land surface characteristics; and selected atmospheric chemical species (e.g. ozone, aerosols, etc.). While most of these observations are now collected on a routine basis as a part of space-based subsystems within the World Weather Watch, there is still a need for additional satellite missions. Future satellite missions will make improved, better calibrated and better geographically located observations of these parameters and, in addition, will monitor key atmospheric constituents such as greenhouse gases, aerosols, chemical precursors to ozone depletion, latent heat fields, wind fields, and ocean biomass and ocean colour.

45. Examples of advanced satellite missions are Advanced Earth Observation Satellite (ADEOS) (Japan), Tropical Rainfall Measuring Mission (Japan and United States), Earth Observing System (United States), ENVISAT (ESA), RADARSAT (Canada), and Sea-viewing Wide Field-of-view Sensors (SeaWifs) (United States). Together, they have been and are being developed to address key environmental issues reflected by the requirements of the World Climate Research Programme, the Global Climate Observing System, the Global Ocean Observing System, the Global Terrestrial Observing System and others (see section VIII).

46. Critical scientific issues and objectives include:

(a) Characterizing and documenting long-term climate variability and trends through systematic global observations of the climate system and its external drivers;

(b) Understanding the nature of key parameters driving changes in the climate system and identifing the causal factors of observed climate variations and feedback processes that govern the response of the climate system;

(c) Assessing the predictable part of long-term climate variability and changes, including regional impacts, through the combined application of observations and global models.

IV. OZONE DEPLETION

47. Ozone is the only greenhouse gas that strongly absorbs solar radiation at the ultraviolet end of the spectrum and primarily in the stratosphere. Stratospheric ozone protects the Earth's surface from harmful solar ultraviolet radiation (especially UV-B) and plays an important role in controlling the temperature structure of the stratosphere by absorbing both incoming solar ultraviolet radiation and outgoing terrestrial long-wave radiation.

48. A reduction in stratospheric ozone can modify surface temperature through two competing processes: (a) more solar radiation transmitted to the surface-troposphere system, thereby contributing to a surface warming; and (b) a cooler stratosphere owing to decreased ultraviolet absorption and less long-wave emission to the troposphere and the surface, leading to a surface cooling tendency. The solar warming (a function of total column amount of ozone) and the long-wave cooling (a function of the vertical distribution of ozone) are of similar magnitude. Thus, the magnitude as well as the increase or decrease in surface temperature depends critically on the magnitude of the ozone change which, in turn, depends strongly on altitude, latitude and season.

49. Because ozone absorbs ultraviolet and infrared thermal radiation, a change in ozone amounts can either increase or decrease the Earth's temperature depending on the change in the ozone profile. A reduction of stratospheric ozone is also thought to have potentially serious biological consequences. An increase in the intensity of UV-B at the Earth's surface is expected to increase the incidence of skin cancer and decrease the

productivity of marine biota, thus affecting the biological carbon pump. The latter effect could lead to an increase in the concentration of CO_2 in surface waters and, consequently, the atmosphere. Observing and monitoring the total column ozone content and the vertical distribution of ozone is considered to be of critical importance. Stratospheric ozone is photochemically controlled by species in the oxygen, hydrogen, nitrogen, chlorine and bromine families. The increasing atmospheric loading of halocarbons, in particular CFCs, is thought to be primarily responsible for the ozone hole and is the reason for the regulatory measures agreed upon under the Montreal Protocol.

50. Although isolated ozone column content observations were made in the 1920s, systematic global observations of total ozone to study its long-term evolution started at the end of the 1950s with the Global Ozone Observing System coordinated by WMO and now a component of the Global Atmosphere Watch (GAW). Since 1950, fairly extensive observations of the ozone vertical profile have been carried out using ground-based Dobson spectrophotometers and balloon-borne measurements at many locations around the world.

51. The beginning of ozone observations from satellites raised the difficult question of sensor stability and calibration. Because of insufficient calibration, Antarctic ozone depletion was discovered by ground-based studies in the late 1970s to mid 1980s and not by satellite observations; however, this demonstrates the necessary complementarity between space observation programmes and ground-based observations. Today, ozone satellite observations are a key element in the day-to-day monitoring of stratospheric ozone. They are providing in near real-time a very detailed structure of the horizontal distribution of ozone. Because of their global view, they are an essential input to the numerical modelling of stratospheric ozone, providing indispensable information for understanding stratospheric ozone processes that lead to its destruction during the Antarctic, or Arctic, springs.

52. The Upper Atmosphere Research Satellite (UARS) of the National Aeronautics and Space Administration (NASA) of the United States has obtained more than six years of global data on atmospheric chemistry, energy input and dynamics. The data have confirmed definitive links between depleted ozone levels and chlorine chemistry and confirmed that technologically produced compounds, primarily CFCs, are the source of the stratospheric chlorine that catalytically destroys ozone. Data from the total ozone mapping spectrometer (TOMS) instrument on board the Nimbus 7 satellite have shown that globally averaged concentrations of total ozone decreased to unprecedented low values in the early 1990s.

53. The ozone hole over the Antarctic produced the lowest values of ozone ever recorded in 1993. During the same period, record levels of UV light were measured at the surface in Antarctica. At one monitoring site, UV-B, the part of the spectrum believed to be the most harmful to living organisms, was recorded at levels 44 per cent higher than in 1992. Ozone concentrations in 1994 were reported to have been as low as the 1993 concentrations. Satellite observations, combined with measured changes in clouds and aerosols, have been used to infer ground-level ultraviolet (UV-B) radiation. Poleward of about 40 degrees latitude, statistically significant increases have been calculated for the period 1979-1992. The largest increases of ground-level UV-B radiation occurred at higher latitudes, in winter and spring. At 45 degrees North latitude (e.g. Portland, Oregon; Minneapolis; Montreal; southern France; northern Italy; Bosnia), the springtime exposure to DNA-damaging and erythemal (sunburn-inducing) radiation has been calculated to have increased by 8.6 and 5.1 per cent, respectively, in the past two decades. Over highly populated areas at 55 degrees North latitude (e.g. United Kingdom of Great Britain and Northern Ireland, Scandinavia, Russia), springtime increases have been even larger.

54. Critical scientific issues and objectives include:

(a) Characterizing the global distribution of ozone, chemically active trace constituents such as photochemical oxidants, aerosols and related meteorological parameters;

(b) Understanding the processes responsible for the chemical transformation of trace constituents, the role of aerosols in affecting atmospheric chemistry and the transport of trace constituents between the troposphere, stratosphere and the upper atmosphere, and between the troposphere and the Earth's surface;

(c) Modelling quantitatively the trace constituent composition of the troposphere/stratosphere system through the combined application of observations and global models.

V. TECHNOLOGY-INDUCED CHANGES IN THE GLOBAL ENVIRONMENT

55. Technological advances over the past several decades have made a substantial contribution to transportation systems (and mobility), agricultural food production and distribution systems, water availability, power generation and distribution, and indeed the information age but as was realized *ex post facto*, at a considerable cost to the environment. Many technological advances are known to have negative impacts on the environment and on the health of human, plant and animal life.

56. An example of the effect of human activity on the global environment is the pollution of the atmosphere, water and soil. Atmospheric pollution, most visibly caused by the use of fossil fuels as an energy source for transportation, causes urban smog and acid rain,* which not only damages vegetation, acidifies the soil and causes various health problems but also pollutes rivers and lakes and destroys forests.

57. Biomass burning is a major source of air pollution in many developing countries in the tropics, since the burning of bushes and grasses is the most common way of preparing land for farming. Fires from biomass burning represent a major source of carbon dioxide, nitrous oxide, hydrocarbons and sulphur dioxide in the atmosphere. Biomass burning is a significant source in the emission of methane and could represent one fourth of total methane emission in tropical regions.

58. Pollution of the atmosphere by the emission of sulphur dioxide and sulphur trioxide is one of the problems posed by petroleum refineries in oil-producing countries. Noxious gaseous effluents and gas flaring from petroleum refineries include hydrocarbon vapours. Discharges from manufacturing industries pollute rivers, lakes and, increasingly, the oceans, which were once thought to be reservoirs of infinite capacity to absorb waste. Many coastal zones now have serious problems.

59. Advanced agricultural methods have led to high crop yields in some parts of the world, but the excessive use of pesticides and fertilizers contaminate the soil and bodies of water into which they are vented by exhaust, run-off and percolation. Thus, sustainable resource management is becoming a critical issue worldwide, as was confirmed by the United Nations Conference on Environment and Development held from 3 to 14 June 1992 at Rio de Janeiro.

60. The problems of soil and water degradation and environmental damage are not uniquely due to technology. In some developing countries, overpopulation, overgrazing and the use of wood as fuel have led to extensive deforestation and have caused equally serious problems of soil erosion and degradation, desertification, water contamination, loss of biodiversity etc. All of the above are considered non-sustainable practices on account of their increasing impact on the environment.

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*Acid rain is a generic term for any acidic precipitation, i.e. rain, snow, sleet, hail, mist, fog. About 30 per cent of air pollutants mix with water in clouds and eventually fall as precipitation. Sulphur dioxide is the main source of acid rain, with contributions from the oxides of nitrogen.

61. International action has been taken because of the serious consequences of CFCs, which are used as refrigerants, aerosol propellants, foam blowing agents and solvents for cleaning. In many countries chemical industries have been developing alternatives to CFCs. Many Governments have now signed the Montreal Protocol on Substances that Deplete the Ozone Layer, adopted on 16 September 1987 which, together with amendments agreed in London in 1991 and Copenhagen in 1992, requires that the manufacture of CFCs be phased out by the year 1996 in industrialized countries and by 2006 in developing countries. The third session of the Conference of the Parties to the United Nations Framework Convention on Climate Change which took place in 1997 in Japan also considered further actions with respect to ozone depletion in the atmosphere and the role of CFCs and ozone as greenhouse gases.

62. Aeronautical and space transportation systems inject combustion products, including ozone depleting chemicals, into the upper levels of the troposphere and lower stratosphere. At cruise altitudes, aircraft emit nitrogen oxides, which are key elements in ozone photochemistry. Aircraft also emit other chemicals that influence the Earth's radiation budget, namely water, carbon dioxide and soot/aerosols. Aircraft exhaust emitted at cruise altitude persists far longer than that emitted near the ground, making cruise emissions a global issue. Emissions from aircraft also contribute to cirrostratus cloud layers which block solar radiation from reaching the Earth's surface. The precise impacts of these activities are as yet speculative. More careful monitoring and research is required in order to develop guidance to policy makers, particularly as the aircraft industry projects a substantial increase in passenger traffic over the next 20 years.

63. Other technology-induced changes include the impact of urbanization, which leads to urban "heat islands" that alter the local climate, increase water run-off and transport polluting chemicals into bodies of water and the surrounding subsoil, and cause an increased demand for cooling in all countries in the warmer areas of the world.

64. In practice, it is very difficult to distinguish between changes in the global environment caused by human activity and natural changes, such as the solar activity effects described earlier, volcanic eruptions, earthquakes and tsunamis, hurricanes, cyclones, typhoons, floods, droughts and phenomena such as El Niño. The use of remote sensing technology to monitor such effects is discussed in more detail in the background paper on management of Earth resources (A/CONF.184/BP/3).

65. Important scientific issues and objectives include:

(a) Monitoring atmospheric/tropospheric pollutants, aerosols and other chemical species;

(b) Observing and monitoring changes in land use practices and vegetation (including deforestation);

(c) Observing and monitoring the discharge of rivers into inland water bodies and coastal zones;

(d) Understanding the interaction between the by-products of technology and the environment and modelling its impact;

(e) Developing a pollutants' distribution model at national, regional and global levels;

(f) Observing and monitoring natural effects on the global environment.

VI. WEATHER FORECASTING AND NATURAL DISASTER WARNINGS

66. Weather forecasting has been crucial to all societies for millennia. The weather at any given location is a result of complex interactions between local, regional and global aspects of solar radiation and atmospheric circulation and dynamics. Atmospheric circulation, in turn, is determined by internal dynamic and thermodynamic processes and interactions with oceans, land surfaces and vegetation, and the cryosphere. If a weather forecast is to be extended beyond a few hours, larger geographic areas are involved as also are the dynamics of the interactive components of the Earth system such as the oceans.

67. Modern weather forecasts require the time integration of numerical models, using the most powerful supercomputers available. Using the output from global models, high resolution (nested) regional and higher resolution models are run to provide more specific characteristics of weather systems, such as precipitation amount. Extending weather forecasting beyond 5 to 7 days requires coupled models that take into account the dynamics of changes in the oceans. Major emphasis is now being placed on the development of seasonal to inter-annual prediction capability on account of the lead-times required for the management of natural and industrial resources, such as agriculture, water supplies and energy production and distribution.

68. All of these models require global observational data, normally gathered once or twice a day. *In-situ* observations are made globally approximately every six hours and transmitted to processing centres, where they are combined with space-based data, available on a continuous basis. Using sophisticated data assimilation techniques, weather forecasts can be made for 24 hours to a week; extended-range forecasts up to several weeks or a month are also possible. For seasonal to inter-annual forecasts, which are used to monitor such phenomena as El Niño, atmosphere-ocean coupled models, which require substantially more observations of the Earth system, are used. Current satellite systems describe storm and major weather systems and provide operational data on the temperature and moisture structure of the atmosphere, sea-surface temperatures, winds, and clouds.

69. The accuracy and timeliness of weather forecasts have improved significantly since the launching of weather satellites. Today every part of the globe can be viewed at frequent intervals from both polar orbiting and geostationary satellites. Since the first weather satellite was launched in April 1960, observations from space of the Earth's atmosphere and the weather systems embedded in it have developed rapidly in quality and quantity. The constellation of just five geostationary satellites has the advantage of covering almost the whole globe from "fixed" positions above the equator. These satellites can provide data every half an hour (or at shorter intervals) to capture the development of fast-growing storms. Visual and infrared sensors provide almost continuous day and night coverage. Countries and regions that currently have geostationary meteorological satellites include China (Feng Yun series), Europe (METEOSAT series), India (Indian National Satellite System for Television and Telecommunications (INSAT)) series, Japan (geostationary meteorological satellite (GMS) series), the Russian Federation (Electro series) and the United States (geostationary operational environment satellite (GOES) series).

70. Most operational polar orbiting meteorological satellites are provided by the Russian Federation (Meteor series) and by the United States (NOAA series). The constellation of operational geostationary and polar orbiting satellite systems in support of meteorology will continue to expand in the future. There is an increasing trend of more joint satellite missions, both on a national basis (e.g. by merging military and civilian systems) and through international cooperation. Newly developed environmental monitoring spacecraft include, for example, the METOP Earth Explorer Mission, the Tropical Rainfall Measuring Mission (Japan/United States), Earthwatch (Europe), and polar-orbiting environmental satellites (POES) (United States). These missions will carry more advanced and complex environmental monitoring instrumentation than that included on current missions.

71. The observations collected should be in a form conducive to integrated data assimilation in forecast and prediction models. A primary aim is to improve the capability to predict socio-economically important weather and climatic events and thereby aid operational managers and decision makers involved in the management of resources such as agriculture, water supplies, energy, transport and tourism.

72. Space-based and airborne observations also support the detection and tracking of a broad range of natural disasters such as cyclones and other extreme weather conditions, drought, floods, forest fires and earthquake damage. On longer time-scales, they provide the only source of quantitative information on desertification, deforestation, land degradation etc. Recent and planned missions will also provide critical data and information on volcanic eruptions and their potential impact by monitoring atmospheric aerosols and dust. Improved instruments on board the next generation of satellites will obtain much more accurate data on wind, temperature and moisture fields and on the concentration and distribution of greenhouse gases and gases involved in ozone chemistry.

73. The methodology and space technology that could be used for natural disaster warning is discussed in more detail in the background paper on disaster prediction, warning and mitigation (A/CONF.184/BP/2).

74. Important scientific issues and objectives include:

(a) Developing remotely sensed observations and using them, together with *in-situ* observations, to monitor, describe and understand climate system variability, ranging from a few days to monthly, seasonal and to inter-annual fluctuations;

(b) Improving the coverage (in space and the parameters/variables needed) for the calibration and validation of present and planned satellite and remote sensing observations;

(c) Improving remote sensing data retrieval algorithms so that the derived geophysical parameters are more representative of direct measurements;

(d) Improving the direct input of globally observed satellite measurements into global models.

VII. SOCIAL AND ECONOMIC ASPECTS

75. In recent years, there has been increasing worldwide recognition of the environmental impacts of technological development, growing populations and economic development and of the finite resources of the Earth system and its ability to support life. Current practices cause considerable damage to natural ecosystems and the life support systems by altering the atmosphere and polluting the air, water and soil of the planet. While the environmental stress caused by each country is different, all nations inadvertently participate (for different reasons) in the process. Much of the damage done may be irreversible if current practices continue.

76. Short-term social and economic benefits have often been the primary drivers of human actions, without due regard to the environmental damages and possible depletion of natural resources. A common belief has been that the Earth's supply of natural resources, as well as its capacity to absorb the impact of human actions, is unlimited. It has taken several generations to understand that this assumption is invalid, even in the case of the oceans that occupy over 70 percent of the Earth's surface. At the present stage of human development, longer-term planning and thinking will be of direct social and economic benefit. In fact, an over-riding concern is that irreversible damage could occur before corrective actions are taken. Of course, it is well understood that it will take some time before industrial, social, economic and cultural practices adjust to this reality. It is also widely acknowledged that immediate or drastic actions could cause serious economic disruption that must be

avoided if at all possible. That is, short-term actions can be justified as long as there is a factual understanding that these actions are necessary but cannot be sustained over time. They need to be embedded in comprehensive plans for the long term, based on scientific observations and analysis.

77. Human health has also become an important issue. The destructive impact of El Niño on human habitats and the discharge of agricultural fertilizers (nutrients to coastal algae), pollutants and pesticides (concentrated in oysters, clams, and shell fish) and contaminants containing heavy metals such as mercury have caused health problems in many regions of the world.

78. International testimony to the above is reflected in many international agreements, among which are the following:

Agenda 21[1] and the work of the Commission on Sustainable Development
The United Nations Framework Convention on Climate Change and the work of IPCC
The United Nations Convention to Combat Desertification in those Countries Experiencing Serious Drought and/or Desertification, particularly in Africa
The Convention on Biological Diversity[2]
The Vienna Convention for the Protection of the Ozone Layer and its Montreal Protocol.

79. Space-based observations cannot monitor social and economic activity as such but can provide information on global effects of urbanization, deforestation, coastal algae blooms, sediment discharge into the oceans and various other precursors to environmental hazards.

80. Critical scientific issues and objectives include:

(a) Improving scientific knowledge and understanding of global change, which will reduce the vulnerability of human and ecological systems to major environmental changes. More complete and focused scientific research can provide the foundation for building strong national and international societies by advancing economic growth and ensuring adequate food supplies and the availability and quality of fresh water, while ensuring the integrity of the natural environment—the key issue underlying the concept of "sustainable development";

(b) Developing the capability to distinguish between human influences on climate and natural ecosystems and those arising from natural variability;

(c) Developing the capability to understand and predict the social and economic impact of existing practices (technological, social, economic and cultural) that might be detrimental to future generations and national economic/social systems;

(d) Investigating alternate economic development strategies that are less harmful to the environment;

(e) Establishing global monitoring systems to provide the accurate quantitative information needed by policy makers to implement decisions to correct irreversible trends in the health of natural ecosystems and food/water/energy supply systems. Included should be the monitoring (by all countries) of land surfaces, land use, vegetation cover and deforestation, urban expansion, energy and transportation needs etc.;

(f) Developing and implementing the capability to monitor the health of coastal zones and the oceans in general.

VIII. PROMOTION OF INTERNATIONAL COOPERATION IN THE EARTH SCIENCES

A. International research programmes

81. Understanding and modelling the fundamental nature of the Earth system and its environment requires detailed observations of the atmosphere, the hydrosphere and components of the hydrological cycle, the land surface and the biosphere, the oceans, the cryosphere and the radiation budget of the planet. Such an endeavour requires worldwide cooperation. No single country or region could possibly undertake the task by itself. For this reason, international scientific research institutions have organized three cooperative global change research programmes:

The World Climate Research Programme (WCRP) which is a part of the World Climate Programme

The International Geosphere-Biosphere Programme (IGBP)

The International Human Dimensions Programme of Global Environmental Change (IHDP, formally HDBP)

These and other international programmes are coordinated at several levels, including scientist-to-scientist, agency-to-agency, and Government-to-Government, through a broad range of multilateral and bilateral organizations and arrangements. The International Council of Scientific Unions (ICSU) provides strong leadership for the scientific planning of many of the key international programmes.

82. The issues related to the state of scientific understanding on the global environment are assessed internationally through the involvement of thousands of scientists from over 150 countries in critical reviews of the recently published scientific literature. Recent assessments include those of IPCC, carried out by its three IPCC working groups on:

The state of scientific knowledge with respect to the climate system, including possible changes as a result of human activity

The potential impact of, adaptation to and mitigation measures for global change

Cross-cutting issues, including the economic implications of climate change and of selected emission scenarios

IPCC is currently preparing four special reports in response to requests from the Conference of Parties to the United Nations Framework Convention on Climate Change on: regional impacts of climate change (1997); atmospheric effects of aviation (1998); technology transfer (1999); and emissions scenarios (1999).

B. Coordination of operational and research satellite programmes and missions

83. *Global Climate Observing System (GCOS)*. The objectives of GCOS cover a broad range, including: climate system monitoring; climate change detection; climate impacts and response monitoring, especially in terrestrial ecosystems; data for applications to national economic development; and research towards improved understanding, modelling and prediction of the climate system. GCOS planning takes a broad and comprehensive view of the observational requirements for climate information which need to cover the atmosphere, oceans, land surfaces and the biosphere and cryosphere. Both surface-based and space-based observations are necessary, as is a comprehensive data system. GCOS is a phased programme, building upon the present observational capabilities of the operational and research programmes of participating countries. For

the atmosphere, close coordination is maintained with ongoing WMO programmes. GCOS is currently examining the availability of data from operational systems such as the World Weather Watch, the Global Atmosphere Watch and operational hydrology programmes. Based on these assessments, recommendations will be made on enhancements or new observations needed to ensure that climate data requirements are met while the data collected are in concert with existing programmes.

84. The scientific scope of GCOS was thoroughly reviewed and developed in 1995. The detailed scientific plans for GCOS considered the full scope of issues including the requirements of users, the contributions of existing research and operational programmes and data systems, and the participation of both international and national organizations. The scientific scope includes the atmosphere, oceans, land surfaces, cryosphere, hydrosphere and ecosystem processes. With the completion of these important plans and documents in 1995, GCOS entered the implementation phase in 1996. It is expected that as GCOS continues to be implemented, countries will see benefits not only from improved climate predictions, but also in planning for sustainable development and the assessment of the impacts of climate change on agricultural and natural ecosystems.

85. *Global Ocean Observing System (GOOS)*. Based on long-term monitoring of ocean conditions, GOOS facilitates forecasting of ocean conditions for the benefit of coastal states and national and international marine users. GOOS is being implemented in five phases, culminating in performance monitoring and improvement after 1997. The initial focus of GOOS was on coastal climate, living marine resources and the health of oceans, all of which have requirements for space-based data.

86. Several aspects of GOOS are being implemented through national and regional efforts, as follows:

(a) Six pilot projects in the Baltic, Arctic, Mediterranean Sea, Black Sea, North West Shelf and Atlantic to be implemented by the Euro-GOOS Association, comprising 22 operational agencies from 14 countries;

(b) The Tropical Ocean and Global Atmosphere (TOGA) programme and the TOGA Automated Observations (TAO) array of moorings for ENSO predictions in the tropical Pacific, led by the United States;

(c) The PIRATA array in the tropical Atlantic, led by Brazil;

(d) The five coastal GOOS projects being developed in the United States.

In addition, GOOS is developing a Global Ocean Data Assimilation Experiment (GODAE) to learn how to assimilate collections of satellite and other data into advanced numerical models.

87. *Global Terrestrial Observing System (GTOS)*. This system was established in 1996 by five international organizations: UNEP, Food and Agriculture Organization of the United Nations (FAO), United Nations Educational, Scientific and Cultural Organization (UNESCO), WMO and ICSU. Unlike the global observing systems that exist for climate and for oceans, no single organization can provide comprehensive information (or the means for gaining access to it) on land and water resources, biodiversity and pollution impacts. The central mission of GTOS is to address this problem by linking existing networks and terrestrial observing systems to provide policy makers, resource managers and researchers with access to the data needed to detect, quantify, locate, understand and warn of changes (especially reductions) in the capacity of terrestrial ecosystems to support sustainable development. This is achieved by focusing on five issues of global concern: changes in land quality; availability of freshwater resources; loss of biodiversity; pollution and toxicity; and climate change.

88. *Global Observing Systems Space Panel (GOSSP)*. GOSSP was established in 1997 to coordinate the scientific requirements arising from GCOS, GOOS and GTOS under the auspices of the United Nations system

Asia; global changes have a dramatic impact on these areas. Also, developing countries are not just passive objects in the process of global change. On the contrary, they have a major impact on global change, as evidenced by forest fires in Indonesia, biomass burning in Africa and deforestation in the Amazon basin.

93. Although developing countries have limited resources to implement extensive research or observation programmes, the benefits of collaborative activities with developed countries are substantial. Such collaboration has been encouraged by the United Nations system, non-governmental international scientific organizations, such as the International Council of Scientific Unions, and various other non-governmental organizations and foundations. The benefits for developing countries are particularly clear in the area of applications for the products of global observing systems and the output products of monitoring (e.g. El Niño and its impacts), global models and assessments of the state of the Earth's environmental system.

94. The United States Geological Service, in partnership with the United States Agency for International Development and the Ministry of Environment of Senegal, has been developing a long-term monitoring framework to better understand and document the rapid changes occurring in Senegal's environment. Geographers, ecologists and social scientists are working together as a team to better understand the human dimensions of environmental change, using biophysical data collected over time at hundreds of field sites and satellite remote sensing data.

95. Over a 30-year period, satellite remote sensing data have been used to map trends in soil erosion, forest degradation from charcoal production, deforestation, agricultural expansion, the breakdown of the traditional fallow agricultural system, habitat fragmentation and the loss of biodiversity. These trends are based on comparisons between the earliest high-resolution declassified satellite images from the Corona Program of the United States, acquired in the mid-1960s and Land remote sensing satellite (LANDSAT) images from the 1980s and 1990s. Since 1986 and 1988, respectively, Systeme pour l'observation de la Terre (Experimental Earth observation system (SPOT) and Indian remote sensing satellite (IRS) images have been extensively used worldwide for continuous monitoring of land use, vegetation and the environment. In addition, land use/land cover change is being analysed through aerial videography and advanced spatial modelling. The monitoring framework is applicable to Africa and other parts of the world, including the United States.

96. Many developing countries such as China, India, Morocco and others, are very active in global environmental research; some, such as Indonesia, Lebanon and Nigeria, are starting cooperation programmes. Many developing countries are located near the equator, where specific effects in the ionosphere and upper atmosphere take place. Because there is a deficit of ground observatories in this region, maximal effort should be directed towards strengthening the local infrastructure and facilities. At the same time, data evaluation methodology and theoretical research should not be overlooked.

97. Examples of collaborative arrangements involving the direct participation of developing countries are the emergence of regional research and applications networks throughout the world such as those in the Asia-Pacific region (APN), in Europe-Africa (ENRICH), and in the Americas. Sixteen countries have signed an agreement to establish the Inter-American Institute (IAI) for Global Change Research; the IAI Directorate is located by the IAI Executive Council at the National Institute for Space Research of Brazil. The international commitment to build capacities for global change research in the developing world is further reflected in the Global Change System for Analysis, Research and Training (START), a joint effort of IGBP, IHDP and WCRP. The START regional research networks promote focused research and training on regional issues of global importance, integrate and synthesize research results, and provide input to decision makers at national and regional levels.

98. Developing countries still tend to be under-represented on *in situ* data gathering programmes. The concerns of developing countries are relevant particularly in the context of the GTOS programme, which could usefully have greater input from *in situ* data gathering stations in developing countries. Of the three global monitoring

systems (CGOS, GOOS, GTOS), the land focus of GTOS is the most relevant to developing countries, but GTOS is the least developed of the three systems. Activities of IGOS in promoting the continuity of data and the transition from research to operational systems can certainly be of substantial help to developing countries.

Notes

[1]*Report of the United Nations Conference on Environment and Development, Rio de Janeiro, 3-14 June 1992* (United Nations sales publication, Sales No. E.93.I.8 and corrigenda), vol. I: *Resolutions adopted by the Conference*, resolution 1, annex II.

[2]See United Nations Environment Programme, *Convention on Biological Diversity* (Environmental Law and Institutions Programme Activity Centre), June 1992.

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THIRD UNITED NATIONS CONFERENCE ON THE EXPLORATION AND PEACEFUL USES OF OUTER SPACE

DISASTER PREDICTION, WARNING AND MITIGATION

Background paper 2

The full list of the background papers:

1. The Earth and its environment in space
2. Disaster prediction, warning and mitigation
3. Management of Earth resources
4. Satellite navigation and location systems
5. Space communications and applications
6. Basic space science and micro gravity research and their benefits
7. Commercial aspects of space exploration including spin-off benefits
8. Information systems for research and applications
9. Small satellite missions
10. Education and training in space science and technology
11. Economic and societal benefits
12. Promotion of international cooperation

V.98-53835 (E)

CONTENTS

		Paragraphs	*Page*
PREFACE			3
SUMMARY			4
I.	NATURAL DISASTERS	1-13	5
	A. Description	1-3	5
	B. Economic and social impact	4-7	5
	C. Increasing vulnerability	8-13	7
II.	DISASTER MANAGEMENT	14-53	8
	A. Information needs	14-20	8
	B. Contributions of space technology to information needs	21-44	11
	C. Economic and social benefits	45-53	16
III.	INTERNATIONAL COOPERATION	54-64	19
	A. Global and regional programmes and proposals	54-62	19
	B. Education, training and technology transfer	63-64	21
IV.	SOME SELECTED ISSUES OF INTEREST TO MEMBER STATES	65-75	21
	A. Need for adequate infrastructure for information-exchange	65	21
	B. Need for higher national priorities for disaster management activities	66-69	22
	C. International cooperation	70-73	22
	D. Access to satellites during emergencies	74	23
	E. Access to relevant information and techniques	75	23

PREFACE

The General Assembly, in its resolution 52/56, agreed that the Third United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE III) should be convened at the United Nations Office at Vienna from 19 to 30 July 1999 as a special session of the Committee on the Peaceful Uses of Outer Space, open to all Member States of the United Nations.

The primary objectives of UNISPACE III will be:

(a) To promote effective means of using space technology to assist in the solution of problems of regional or global significance;

(b) To strengthen the capabilities of Member States, in particular developing countries, to use the applications of space research for economic and cultural development.

Other objectives of UNISPACE III will be as follows:

(a) To provide developing countries with opportunities to define their needs for space applications for development purposes;

(b) To consider ways of expediting the use of space applications by Member States to promote sustainable development;

(c) To address the various issues related to education, training and technical assistance in space science and technology;

(d) To provide a valuable forum for a critical evaluation of space activities and to increase awareness among the general public regarding the benefits of space technology;

(e) To strengthen international cooperation in the development and use of space technology and applications.

As one of the preparatory activities for UNISPACE III, the Office for Outer Space Affairs of the Secretariat has prepared a number of background papers to provide Member States participating in the Conference, as well as in the regional preparatory meetings, with information on the latest status and trends in the use of space-related technologies. The papers have been prepared on the basis of input provided by international organizations, space agencies and experts from all over the world. A set of 12 complementary background papers have been published and should be read collectively.

Member States, international organizations and space industry planning to attend UNISPACE III should consider the contents of the present paper, particularly in deciding on the composition of their delegation and in formulating contributions to the work of the Conference.

The Secretariat gratefully acknowledges the contributions that have been made by several specialists and organizations in the preparation and review of this paper, in particular: European Space Agency (ESA); Canadian Space Agency (CSA); National Aeronautics and Space Administration (NASA), Centro nacional de prevención de desastres (CENAPRED) of Mexico; National Oceanic and Atmospheric Administration (NOAA) of the United States of America; Centre royal de télédétection spatiale of Morocco; Indian Space Research Organization (ISRO); Manila Observatory of the Philippines; National Institute of Aeronautics and Space (LAPAN) of Indonesia; International Decade for Natural Disaster Reduction Secretariat; International Space

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SUMMARY

The present paper presents an overview of the various types of hazards, their impact on development and how space technologies can be used to enhance the effectiveness of all phases of disaster management.

The social and economic costs of natural disasters are rising. There has been a five-fold increase in economic costs in the past 30 years. On average, over 110,000 persons lose their lives each year on account of natural disasters. The rising trend is attributed to increasing vulnerability of the world's population. Vulnerability is linked to several factors, including population pressure, declining resource base, degradation of the environment, illiteracy and poverty. National programmes for disaster management should therefore aim at reducing the various elements of vulnerability as part of an integrated sustainable development strategy through the cost-effective use of space technologies.

Specific stages of disaster management programmes are pre-disaster planning and preparedness, forecast and warning, emergency response and rehabilitation. The main needs of these activities are information and data exchange, education and training, technology transfer and emergency communications. Space technologies, in particular satellite telecommunications, remote sensing (including optical and radar systems), satellite meteorology and geo-positioning systems, respond to these needs. These technologies offer a source of information that complements that available from other sources, particularly ground-based sources.

Notable examples of space technology applications include the use of (a) high spatial resolution remote sensing imagery for mapping hazardous zones during land-use planning, (b) information from Global Positioning System (GPS) satellites for emergency location and navigation purposes, especially within the context of search and rescue operations, (c) satellite telecommunications systems for the issue of warnings of impending disasters or for sending distress signals, especially from ships and aircraft, (d) satellite-based mobile telephone systems in emergency instances where the terrestrial networks have been damaged or destroyed, (e) television broadcasts, videoconferencing, data transfer, and Internet services to support a variety of educational activities as well as emergency services, (f) satellites to detect and monitor meteorological hazards, such as hurricanes (typhoons/cyclones) and to facilitate the issue of public warnings, (g) radar and GPS satellites to monitor a variety of geological hazards, including earthquakes and volcanoes, and (h) sea surface temperature and topography measurements to forecast El Niño events.

Some relevant areas of concern in the use of space technology are the need for (a) adequate information exchange infrastructure at the national level to support disaster management, (b) Governments to give high priority to disaster management activities, (c) better international cooperation to facilitate the use of telecommunications equipment, (d) access to relevant space technologies and techniques by developing countries, (e) access to satellites during emergencies, and (f) the enhancement of education and training in matters related to the application of space technology to disaster management.

I. NATURAL DISASTERS

A. Description

1. Natural hazards are natural or human-induced processes or events with the potential to create loss to humans and to their welfare. Many so-called "natural" hazards have both natural and human components. Natural hazards have thus been defined as extreme geophysical events, biological processes and major technological accidents, characterized by concentrated releases of energy or materials that pose a largely unexpected threat to humans. Natural hazards therefore include events such as the following:

Floods
Typhoons
Hurricanes and cyclones
Earthquakes
Tornadoes
Whirlwinds and thunderstorms
Snowstorms
Heatwaves
Cold spells
Volcanic eruptions
Landslides
Avalanches
Tidal waves
Drought
Sandstorms or dust storms
Windstorms
Wildfires
Locust or other insect infestations

2. When the interaction between the human population and a hazard results in the loss, at a sufficiently large scale, of lives, of material possessions or of what is valued by humans, the event is termed a disaster. Many disasters, such as earthquakes, are usually limited in time as well as in space and are disruptive to the social structure and functioning of communities. Others, such as droughts, are more gradual in their onset, but their impact may be no less severe.

3. The most notable natural disasters are due to a few events of a very high magnitude that occur relatively infrequently. Many of these disasters occur repeatedly in certain regions that, owing to natural geophysical characteristics, are susceptible to a variety of hazards (e.g. volcanic eruptions and earthquakes in tectonically active zones or extensive flooding in lowland coastal areas due to tropical cyclones).

B. Economic and social impact

4. More than 3 million people were killed in natural disasters worldwide during the 20-year period 1974-1994. Those disasters brought injury, homelessness and misery to 1 billion others and caused many billions of dollars of property damage. In 1991 and 1992 alone, property damage amounted to 100 billion United States dollars. A single event, Hurricane Andrew, caused US$ 25 billion of damage in the southern part of the United States of America in 1992. On average each year, natural disasters around the world leave 4 million people homeless, injure another 900,000 people and kill 128,000 people.

5. There were 180 reported natural disaster events worldwide in 1996, of which 50 were major, requiring international assistance. It has been estimated that in 1992 the world economy lost more money (US$ 62 billion) from natural disasters in the less developed countries than it spent on development aid (US$ 60 billion). In Bangladesh, for example, more than 5 per cent of gross domestic product (GDP) is lost annually to recurrent natural disasters. In 1970 and 1991, 300,000 and 138,000 lives, respectively, were lost in Bangladesh due to cyclones. In industrialized countries, even major disasters rarely cost more than 0.1 per cent of gross national product; however, it can be 20-30 times more in less developed countries. The relatively small size and specialized nature of the economies of many developing nations make them more vulnerable to the effects of natural hazards than the larger economies of industrialized countries. Also, in many developing countries, disasters recur regularly, principally because of a lack of funds to introduce sustainable disaster-management solutions.

6. The more notable social and economic consequences of natural disasters include the following:

(a) Loss of human lives;

(b) Panic; social disruption (e.g. no sense of community, security or control);

(c) Increase in the likelihood of social unrest or violent conflict;

(d) Damage to the natural resource base and to the environment;

(e) Loss of housing; temporary and/or permanent migration;

(f) Loss of industrial and/or agricultural production (hence employment, income and tax revenue);

(g) Damage to infrastructure (including transportation and communication systems);

(h) Disordered markets and distribution; loss of commerce;

(i) Immediate downgrading of living conditions owing to the deferral or cancellation of other development plans that deal with real social needs;

(j) Short-term reduction in GDP and per capita income;

(k) Imbalances in the fiscal budget as a result of emergency reallocations of expenditure;

(l) Immediate and medium-term inflationary pressure due to market disorders and externally financed reconstruction expenditure.

Approximately 25 per cent of the world's population lives in regions that are at risk of natural disaster. However, the impact of disasters and their secondary effects (e.g. loss of life, property damage and social and economic disruption) are invariably the greatest where poverty-stricken people are concentrated. Asia has been the continent most affected by major disasters, accounting for over 60 per cent of the 45 million disaster-related deaths, and 85 per cent of the 3.7 billion victims of natural disasters, since 1900. Of all those disasters, drought and floods have been responsible for the largest number of deaths (over 53 per cent). About 60 per cent of all deaths due to storm surges have occurred in the low-lying coastal areas of countries bordering the Bay of Bengal and the adjoining Andaman Sea.

7. Two thirds of the world's population live in developing countries. Yet approximately 90 per cent of all natural disasters and 95 per cent of disaster-related deaths occur in developing countries. In the period 1947-1981, for example, there were 3,958 and 3,174 disaster-related deaths per 1 million of population in Bangladesh and Guatemala, respectively. In contrast, in Japan and the United Kingdom of Great Britain and Northern Ireland, the corresponding figures were 276 and 89. However, while deaths due to natural disasters in industrialized nations are decreasing as a consequence of effective public policies and technological developments, the level of economic losses is rising (a fivefold increase in economic costs compared with the 1960s). In the period 1986-1996, the economic losses from 64 very large disasters amounted to some US$ 400 billion. It is estimated that economic losses due to disasters in the United States amount to approximately 1 billion dollars per week and that much of those losses are incurred through a few very costly disasters such as hurricanes and earthquakes.*

C. Increasing vulnerability

8. The social and economic costs of natural disasters are increasing worldwide. This tendency is attributed in part to increasing vulnerability in less developed countries, where people are often left more vulnerable to subsequent hazards after experiencing one disaster.

9. Many factors contribute to increasing vulnerability. These include (a) increasing population, with resultant increased densities of people and investments on marginal lands (e.g. increasing use of unsuitable and unsafe lands), (b) unsustainable development practices, especially in marginally productive lands, (c) the inability of Governments faced with a rising population to provide adequate social services, including services related to disaster reduction, (d) degradation of natural resources (e.g. overgrazing of rangelands and overexploitation of forests), (e) increasing insecurity of food and water supplies, (f) rural-urban migration and urbanization pressures that concentrate people in unsafe cities, (g) increasing poverty and illiteracy and increasing numbers of poor people being exposed to hazards, (h) weak institutional capacity for confronting disasters, (i) inadequacy of disaster management measures and forecasting techniques, (j) inadequate participation of local community in disaster management, (k) inadequate training, (l) inadequate communications and transport infrastructure, (m) lack of strict environmental control measures, (n) inadequate market mechanisms to help buffer against disasters and spread risks, (o) increasing global interdependence of economies, leading to more extensive impacts from a single disaster, and (p) global climate changes increasing the vulnerability of certain geographic regions to hazards.

10. While some societal factors tend to increase vulnerability to disasters, there are several technological trends that serve to decrease it. Examples of such positive trends are (a) increased understanding of hazardous processes and phenomena, (b) improved analytical methods, which permit the development and use of complex models, (c) enhanced communications, which permit applications resulting from this new understanding to be communicated in a timely manner, and (d) advanced engineering practices, which have given an improved understanding of the susceptibility of materials and structures together with the development of new approaches to engineering and design. These positive trends, however, must be partially balanced against the negative aspect of an increased reliance on technology, which is often somewhat fragile and sensitive to the impact of hazards.

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*Estimation of economic losses due to disasters is complicated by several factors such as the large (and potentially under-reported) number of smaller disasters, the difficulty inherent in assessing damage in larger disasters, and the effects of secondary losses (e.g. to businesses and employment), as well as possible benefits (e.g. to construction industries). A comprehensive methodology for assessing disaster losses is currently being developed by the United States National Academy of Sciences Board on Natural Disasters.

11. Over the past several years, there has been an increased awareness that the frequency of many hazards—particularly those involving atmospheric or meteorological phenomena—may be not constant but subject to environmental trends. The most pronounced example is that due to short-term climate changes such as the El Niño phenomenon: this is the seasonal-to-interannual fluctuation of ocean and atmospheric currents in the eastern equatorial Pacific, which can alter rainfall and wind patterns and, thus, the occurrence of droughts and floods. Beyond this, on the decadal timescale and beyond, lies the possibility that long-term climate change, induced by anthropogenic increases in carbon dioxide and an enhanced greenhouse effect, will similarly alter the frequency of storms and droughts.

12. The increasing trend in the frequency and impact of natural disasters led the General Assembly, in its resolution 44/236 of 22 December 1989, to proclaim the International Decade for Natural Disaster Reduction, beginning on 1 January 1990. The objective of the Decade is to reduce through concerted international action the impact of natural disasters, especially in developing countries. Governments have been called upon to enact a number of measures, including: formulating national disaster mitigation plans; establishing multisectoral national committees to stimulate and coordinate activities aimed at fulfilling the goals of the Decade; mobilizing support from the public and private sectors; increasing public awareness of risk reduction, relief and short-term recovery activities and enhancing preparedness; paying closer attention to the impact of natural disasters on health care; and improving the early availability of emergency supplies.

13. A target of the Decade is that, by the year 2000, all countries should, as part of their plans to achieve sustainable development, have in place (a) comprehensive national assessments of risks from natural hazards, (b) mitigation plans (and the necessary legal framework) at the national or local level or both, involving long-term prevention, preparedness and community awareness, and (c) ready access to global, regional, national and local warning systems and broad dissemination of warnings.

II. DISASTER MANAGEMENT

A. Information needs

14. Given their significant social and economic costs, it is evident that sustainable development could be considerably enhanced by reducing the impacts of natural disasters. The reduction of vulnerability should, as part of an overall disaster management strategy, be a routine objective of development activities and be integrated in investment decisions.

15. Disaster management involves a series of information-intensive phases: pre-disaster planning, disaster preparedness and forecasting, emergency (disaster) response, recovery and reconstruction. Space technology can play a role in furnishing the information required in each of these phases.

16. *Pre-disaster planning phase*. This phase includes activities aimed at the avoidance or reduction of risks. Risks are assessed through an objective, information-intensive process requiring the evaluation of the characteristics of hazards, such as their probability of occurrence, severity and location, as well as the vulnerability of life and property to such hazards. Typical information-related needs for this phase include the following:

(a) Information access and exchange

(i) How to formulate national disaster mitigation programmes and related policies;

(ii) How to incorporate disaster reduction and risk management in development planning;

(iii) Knowledge of appropriate risk assessment/risk monitoring methodologies, including those incorporating the use of space technologies (e.g. use of automatic transmissions of information via satellite from *in situ* monitoring stations to a central decision-making facility);

(iv) Technical knowledge required to facilitate local implementation of defensive measures (e.g. restrictions regarding the location of residences and facilities in areas where they may be affected by a hazard, such as an earthquake or volcanic eruption);

(v) How to mobilize funds for implementation of disaster-reduction activities;

(vi) Public access to information on hazards;

(vii) Information on appropriate land-use legislation;

(viii) How to revise regulatory policies to allow effective deployment, including trans-border use, of telecommunications equipment during disasters;

(ix) Appropriate implementation of building codes and zoning laws;

(b) Communications and training:

(i) Building up public awareness of and commitment to disaster management and evacuation planning;

(ii) Training of public administrators of disaster management;

(iii) Dissemination of information on hazards;

(iv) Establishment of local pools of expertise and equipment needed to deal with various aspects of disaster management;

(v) Creation of disaster-related database networks;

(c) Regional/international cooperation:

(i) How to pursue regional cooperation in matters related to disaster management;

(ii) How to inform the international community of national disaster management programmes.

17. *Disaster preparedness and forecasting phase*. This phase includes activities that reflect the readiness or degree of alertness of the public to cope with a specific hazard. It also involves action taken in response to an ongoing or impending hazard; action such as hazard forecasting, warning and prediction. (These three terms are used here in terms of increasing probability, and decreasing time; that is, a forecast will be issued sooner than a prediction, but will have a lower level of confidence.) Preparedness also includes action such as stockpiling and training. Typical information-related needs during this phase are:

(a) Hazard forecasting;

(b) Arrangements for the issue of warnings and evacuations;

(c) Information related to stockpiling operations;

(d) Training for emergency workers;

(e) Information related to locations at risk where emergency equipment (e.g. telecommunications equipment) can be pre-positioned.

18. *Emergency (disaster) response phase*. This phase includes activities taken immediately before and after the onset of a hazard to reduce the effects of a disaster after it occurs. The first stage of disaster relief usually involves assessment of the extent and severity of the damage. Subsequently, relief measures such as delivering food, health care and other sustenance are undertaken. Along with this will be the implementation of the first remedial measures (e.g. removing dams caused by lava flows or draining flood water back to rivers). The range of typical information needs includes the following:

(a) The issue of warnings following the identification of an impending hazard and the population at risk;

(b) Plans for implementing evacuations;

(c) Plans for administering emergency relief;

(d) Initial evaluation of the impact of a disaster.

19. *Recovery phase*. Disaster recovery includes those actions required to re-establish the community and its infrastructure. Properly carried out, it also includes remedial mitigation measures to prevent the disaster from happening again. Typical actions undertaken during this phase include: the initiation of efforts to restore the most pressing services and the most essential social infrastructure; the repairing of the transportation infrastructure and public utilities and services; and the building of temporary shelters. This phase is also characterized by the return to normal work and the initiation of projects to deal with the immediate consequences of the disaster. The information needs of this phase include:

(a) Localization of the population affected and their needs;

(b) Localization of damaged/destroyed infrastructure or services;

(c) Determination of the most affected sectors and areas;

(d) Identification of post-emergency projects that require financial and technical assistance;

(e) An assessment of the country's ability to contribute its share to efforts to respond to the needs following a disaster;

(f) Communication with the international donor community (Governments, non-governmental organizations and private sector groups that contribute to international disaster relief).

20. *Reconstruction phase*. This is the period during which the physical infrastructure and services damaged or destroyed by the disaster are restored. Information needs during this phase relate typically to hazard reduction measures, such as the design of hazard-resistant engineering structures.

B. Contributions of space technology to information needs

21. Natural hazards cannot be prevented; however, their social and economic impacts can be reduced through the cost-effective use of appropriate technologies. A number of space-based technologies (e.g. telecommunications, Earth observation, geo-positioning and meteorology)* can contribute to the information requirements of the different phases of a disaster management programme and therefore offer significant potential for minimizing the impact of natural hazards.

1. Satellite meteorology

22. *Satellite meteorology*. Meteorological satellites now monitor the Earth's atmosphere, oceans and land surface in almost real time. In general, the satellites perform the following three major functions: (a) make remote sensing observations that can be converted into meteorological parameters such as cloud cover, cloud motion vectors, surface temperature, vertical profiles of atmospheric temperature and humidity, snow and ice cover, ozone, solar radiation and infrared radiation, (b) collect data from sensors placed on remote fixed or mobile platforms, located either on the Earth's surface or in the atmosphere, and (c) make direct broadcasts to provide cloud-cover images and other meteorological information to users through a direct read-out station.

23. The satellites provide data that are essential for the day-to-day-prediction of local and global weather and for supporting disaster management activities, such as the early warning of meteorological and hydrological hazards and the preparation of disaster situation reports. The meteorological data are also used for monitoring climatic changes.

24. Both geostationary and near-polar orbiting satellites are routinely used for meteorological applications. At present there are three polar orbiting and six geostationary orbiting meteorological satellites. The satellites are provided by China, India, Japan, Russian Federation and United States and by the European Organisation for the Exploration of Meteorological Satellites (EUMETSAT). The abilities of geostationary satellites to provide a continuous view of weather systems make them invaluable in following the motion, development and decay of such phenomena. Even such short-term events as severe thunderstorms, with a life time of only a few hours, can be successfully recognized in their early stages, and appropriate warnings of the time and area of their likely maximum impact can be expeditiously provided to the general public.

25. Polar-orbiting satellite systems provide data needed to compensate for many of the deficiencies in conventional surface-based observing networks, especially over marine regions and sparsely inhabited land areas. In their near-polar orbit, such satellites acquire data from all parts of the globe in successive revolutions, each of which takes just over an hour and a half. From a relatively low altitude (approximately 800 km), the satellite's sensors can acquire data at high resolution, both spatially and spectrally.

26. Additional meteorological satellites continue to be launched both to replace and to expand existing capabilities. If all currently planned commercial and governmental meteorological satellites are launched, by the year 2010, some 15 geostationary satellites and up to 18 polar-orbiting satellites could potentially be available for use for disaster management

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*Details on specific space technologies are given in other background papers prepared for the Third United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE III). See, in particular, the background papers on the management of Earth resources (A/CONF.184/BP/3), satellite navigation and location systems (A/CONF.184/BP/4), space communications and applications (A/CONF.184/BP/5) and small satellite missions (A/CONF.184/BP/9).

2. Mobile satellite services

27. Mobile satellite services (offering voice, facsimile and data transmission, and paging)* are one of the most effective means of communications in the event of disasters owing to several important advantages that they have over other means of communications: (a) they do not depend on the presence of an existing infrastructure, which may in any event be destroyed or damaged, (b) they are unaffected by ionospheric noise, (c) they are highly portable and can be set up and used anywhere easily and quickly, and (d) they are cost-effective. Several firms offer mobile satellite services.

28. The International Mobile Satellite Organization (Inmarsat) caters to over 80,000 terminals worldwide. Some 5,000 of these are used in disaster management by international organizations, including the Office of the United Nations High Commissioner for Refugees, the International Atomic Energy Agency, the International Committee of the Red Cross, the International Federation of Red Cross and Red Crescent Societies and Médecins sans frontières, various civil protection agencies, and wildfire and rescue services around the world. Among the services offered are voice, facsimile, Internet and data transmission services via laptop-sized satellite stations. The terminals have been used, for example, for monitoring water levels in rivers in Argentina, China, France and India and for ocean monitoring as part of the World Weather Watch of the World Meteorological Organization (WMO). Newly available services that are useful for issuing warnings and community alerts are satellite paging and two-way short messaging.

29. TMI Canada operates the mobile-satellite communications (MSAT) system for mobile voice, facsimile and 2.4 kbps data services; the Australian regional system, Mobilesat, is similar. TMI Canada, together with the American Mobile Satellite Corporation (AMSC) in the United States, forms a regional mobile satellite system with coverage of Canada and the United States. Disaster management agencies, such as the Federal Emergency Management Agency (FEMA) in the United States and Emergency Canada, use these regional systems extensively, not only for coordinating relief, but also for informing people, keeping them in touch with relatives, and helping them to stay calm. MSAT terminals are also used in fixed locations in Canada to help monitor remote forests for outbreaks of fire and in dealing with oil spills. FEMA and the American Red Cross use mobile satellite communications systems during hurricanes and floods and in combating forest fires. To facilitate disaster management, special arrangements are available to governments, municipalities and other organizations that need advanced communications capabilities during natural disasters, industrial accidents, and other emergency situations. These include short-term rentals, special service rates (below US$ 1/min) and 24-hour customer support. A similar disaster warning system, covering 250 strategic locations along the cyclone-prone east coast of India, has been in operation for some time. The system enables decision makers to take appropriate measures to counter impending disasters in a timely manner.

30. Qualcomm, a mobile system using existing Ku-band satellites in Australasia, Europe, North America and South America, provides low-speed data and localization services via mobile terminals. There are approximately 175,000 Qualcomm units in use worldwide, many of which are used for hazardous cargo tracking. Another mobile satellite data system is Orbcomm, a low-Earth orbit (LEO) system operating in the very high frequency (VHF) band, which has been providing commercial data-only service in North America since early 1996. The small Orbcomm units make them particularly suitable for use as personal emergency beacons and for tracking vehicles and equipment.

31. Several new LEO, medium-Earth orbit (MEO) and regional geostationary Earth orbit (GEO) systems are planned; they would provide mobile voice, data, short messaging and paging services that could be of use during

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*Further details on these systems are presented in the UNISPACE III background paper on space communications and applications (A/CONF.184/BP/5).

emergencies. Iridium, a global consortium, will initiate a LEO system consisting of 66 satellites in 1998. Users will be able to access services via small hand-held mobile units with omnidirectional antennas at a planned cost of US$ 3/min for voice and data transmissions of up to 2.4 kbps. Globalstar, another LEO system consisting of 48 satellites, is to begin operations late in 1999 and to offer services at a cost of approximately US$ 1/min. ICO Global Communications is implementing an MEO satellite telephone system with 10 satellites that is expected to become operational in the year 2000, at a cost of just US$ 1/min.

32. Of special interest to the disaster management community are special programmes put into place by satellite operators (such as Inmarsat) that are designed to provide free or low-cost access to satellite capacity during emergencies. Operators of some of the planned systems have already announced their own programmes for satellite access during disasters. Iridium, for example, has plans to offer 1,000 minutes free to handsets allocated to disaster mitigation personnel.

3. Geostationary telecommunication satellites

33. Many geostationary satellite systems (e.g. International Telecommunication Satellite Organization (INTELSAT), Eutelsat, Panamsat, Indian National Satellite system for Television and Telecommunications (Insat), Orion, Anik, Palapa)* are used for main-route or back-up communications in telephony, video and data transmission. These systems play a key role in news gathering and broadcasting and can therefore contribute to increasing public awareness of disasters and to the mobilization of international support during emergencies.

34. Several satellite operators are very much aware of the potential contribution of their systems to disaster management and have put appropriate contingency plans into place. For example, the Nippon Telegraph and Telephone Corporation (NTT) of Japan uses a domestic very small aperture terminal (VSAT) system for disaster back-up communications. VSATs with fixed, small-diameter (0.95-metre) antennas are situated at a total of 17 NTT branch offices and other main buildings throughout Japan for bidirectional communication with the hub stations. Additionally, mobile VSATs with antennas 0.75-metre in diameter are stationed at 23 out of 222 NTT service centres. This configuration ensures communication routes between NTT main and branch offices and service centres during and in the wake of natural disasters, allowing telephone calls, facsimile messages and data communications.

35. Commercial operators of Ku-band and C-band satellites offer portable stations for use during emergencies. Such equipment are provided, for example, by INTELSAT, TELESET, European Telecommunications Satellite Organization (EUTELSAT), ITALSAT and various operators in the Russian Federation and the United States. INSAT operates a disaster warning system of community-based VSATs along the eastern shores of India. In the United States, FEMA leases Ku-band capacity, equivalent to two T1s (2x150 Mbps, or 24 voice channels each), on a commercial Ku-band satellite at all times so that they can have immediate access. The Ku-band terminals are mounted on trucks and on deployment are linked to transportable telephone switches to provide telephone services to disaster field posts.

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*Further details on these systems are presented in the UNISPACE III background paper on space communications and applications (A/CONF.184/BP/5).

4. Navigation and geo-positioning systems

36. The Global Positioning System (GPS) and the Global Orbiting Navigation Satellite System (GLONASS) provide position determination that is used for localization, tracking of equipment and vehicles, and emergency personal beacons. Such navigation and geo-positioning systems* support a wide variety of activities related to disaster management.

37. Geo-positioning systems, in conjunction with data communications satellites, are used to track hazardous cargoes, including radioactive materials. With GPS ground receivers, it is also possible to detect relative ground motions as low as a few millimetres a year between points separated by hundreds of kilometres. Utilizing the maximum precision of GPS, scientists are able to monitor movements of tectonic plates and other seismic hazards. Such monitoring permits the assessment of earthquake risk. The data are also useful in predicting the eruption of volcanoes and the occurrence of landslides. GPS technology, in conjunction with complementary instrumentation, also allows the worldwide study of atmospheric water vapour and provides data needed for understanding potentially hazardous climatic phenomena.

5. Internet and other broadband applications

38. Rapid growth in demand for Internet, multimedia and other broadband services has prompted the development of new broadband satellite constellations in both LEO and GEO. These services can now be used for disaster management. In some countries, the Internet already facilitates public access to map-based information that is useful in reducing vulnerability (e.g. maps showing the locations of flood-plain areas relative to planned building sites).

39. Teledesic, a LEO broadband system consisting of 288 satellites, should be available in the year 2002. It will allow Internet connections via low-power terminals connected directly to computer networks or individual personal computers at speeds of up to 2 Mbps during uplink and up to 64 Mbps during downlink. Several other LEO systems are planned, including M-Star (72 satellites), Celestri (63 satellites), and SkyBridge (64 satellites). Planned GEO broadband systems include Spaceway, Cyberstar, Panamsat and Orion.

6. Remote sensing satellites

40. Remote sensing satellites** provide data that have proved useful for a wide range of applications in disaster management. These include the mapping and monitoring of hydrological and seismic hazards, variables affecting climate and weather, land use, the extent of damage due to volcanic eruptions, oil spills, forest fires, the spread of desertification, and the forecasting of floods and droughts (see table 1).

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*Further details on these systems are presented in the UNISPACE III background paper on satellite navigation and location systems (A/CONF.184/BP/4).

**Further details on remote sensing satellites can be found in the UNISPACE III background paper on the management of Earth resources (A/CONF.184/BP/3).

Table 1. Examples of the uses of space remote sensing in disaster management

Hazard	*Disaster management phase*		
	Mitigation	*Preparedness (warning)*	*Relief*
Earthquakes	Mapping geological lineaments and land use[a]	Geodynamic measurements of strain accumulation[b]	Locating stricken area and mapping damage[c]
Volcanic eruptions	Topographic maps[d] and land-use maps[a]	Detection and/or measurement of gaseous emissions[b,d]	Mapping lava flows, ashfalls, and lahars[a] and mapping damage[c]
Landslides	Topographic maps[d] and land-use maps[a]	Soil porosity; rainfall, slope stability[b,d]	Mapping slide areas[c]
Flash floods	Land-use maps; satellite estimates[a]	Local rainfall measurements[b,d]	Mapping flood damage[c]
Major floods	Flood-plain maps;[b] land-use maps [a]	Regional rainfall; evapo-transpiration[b]	Mapping the extent of floods[a]
Storm surges	Land-use and land-cover maps[a]	Sea state;[a] ocean surface wind velocities[b]	Mapping the extent of damage[c]
Hurricanes	Positions and intensities[a]	Synoptic weather forecasts[b,d]	Mapping the extent of damage[c]
Tornadoes		Nowcasts; local weather observations[b]	Mapping [illegible] amount and extent of damage[c]
Droughts	Soil wetness; vegetation index[a]	Long-range climate models[b,d]	Monitoring vegetative biomass; station communications[a]

[a]Already operational or needs very little research
[b]Research and development required
[c]Requires improved spatial or temporal resolution
[d]Requires improved observation capability

41. Information from remote sensing satellites is combined with other relevant data in geographic information systems (GIS) in order to carry out risk assessment and help identify areas at risk such as flood zones. The ready availability of flood-zone maps tends to discourage the development of housing in areas susceptible to flooding and reduces the magnitude of damage and human suffering caused by any subsequent floods.

42. Outbreaks of cholera in Bangladesh have been associated with seasonal coastal algal blooms and El Niño warm events. El Niño events have also been linked to outbreaks of disease (e.g. typhoid, shigellosis, hepatitis, viral encephalitis, eastern equine encephalitis, malaria and dengue) in other parts of the world. Remote sensing measurements, for example, of ocean colour, sea surface temperature and topography, are useful in mapping algal blooms and in forecasting the onset of El Niño events. These observations indicate the feasibility of devising an early warning system for predicting and monitoring cholera and other diseases based primarily on satellite data.

43. Using the techniques of interferometry and radargrammetry, data from radar satellites are used to forecast volcanic eruptions and earthquakes and form the basis of public warnings by disaster management organizations. Images from the RADARSAT satellite were used in 1996 in the control of a major oil spill off the coast of Wales and in the analysis and preparedness measures in the Canadian flood in 1997.

44. Ongoing research and development will lead to improvements in the measurement of several remotely sensed parameters. These improvements will enhance further the utility of remote sensing satellites for disaster management (see table 2).

C. Economic and social benefits

45. The benefits to society of the use of space technology in disaster management relate to its cost-effective use in the reduction of the impacts, both long-term and short-term, of disasters. Some notable examples of the beneficial application of space technologies are presented below.

1. Emergency communications

46. Natural disasters tend to destroy or severely disrupt terrestrial telecommunication networks. Satellites play a vital role in enabling critical activities, such as the collection and dissemination of disaster and emergency news, the issuance of warnings, the provision of back-up communications for the continuation of government and business activities, and the transmission of data from remotely located sensors, to continue.

Table 2. Remote sensing applications in disaster management to be enhanced by research and development

(R and D = research and development; SAR = synthetic aperture radar)

R and D activities	*Technological approach*	*Applications*
Soil moisture maps and measurements	Passive or active microwave; thermal mapping	Flood warning; drought assessment
Rainfall, rainfall rate	Passive or active microwave; thermal remote sensing of cloud top temperatures	Flood warning; drought assessment
Storm-track monitoring	Improved spatial resolution from geosynchronous orbit; atmospheric winds (lidar); surface winds (scatterometer)	Improved landfall predictions in space, time, and intensity
High spatial resolution mapping	Pointable imagers; improved detector arrays; lower orbits	Detailed land-use and land-cover maps; assessment of landslide vulnerability; topographic mapping; risk mapping of urban and industrial zones
Topographic mapping	Interferometric SAR; high-resolution off-nadir imaging	Flood-plain models; landslide vulnerability; volcanic vulnerability
SAR interferometry	Repetitive SAR observations	Surface deformation for earthquake risk assessment; volcano warning

47. A specific example of the use of satellite technology for emergency communications is the International Search and Rescue Satellite System (COSPAS-SARSAT),* the space segment of which is provided by several nations. Receivers on board several meteorological and navigation satellites are tuned to pick up signals emitted from transmitters activated in distress situations (such as a sinking ship or persons injured in a wilderness area). These signals, depending on the satellite and transmitter features, may take anywhere from a few minutes to a couple of hours to locate the point with an accuracy of about 1 kilometre, or far less if integrated GPS is used. Several thousands of sailors, airline passengers and other individuals in distress owe their lives to this system, which has been operational for over a decade. COSPAS-SARSAT has recently been augmented by geostationary satellite search and rescue payload systems, such as the one on INSAT, which has served to reduce the time for detection of disasters. In addition to COSPAS-SARSAT, the data collection system (DCS) carried on United States geostationary satellites is used for disaster mitigation by many countries. DCS provides data relay from ground-based sensors in a wide variety of applications, ranging from the monitoring of earthquakes to the measurement of rainfall.

2. Hazard forecasting and monitoring

48. By allowing society time to prepare for or avoid an impending hazard, forecasting and early warning systems have dramatically reduced deaths, injuries, property damage and other economic losses. Space technologies, particularly telecommunications, remote sensing and geo-positioning, are a key component of these systems. Space technology also provides timely and comprehensive information on ecological conditions conducive to support the massive development of desert locusts, thereby helping countries to apply appropriate combative measures in the field and ultimately to enhance food security (e.g. the African Real-Time Environmental Monitoring using Imaging Satellites (ARTEMIS) and the Direct Information Access Network for Africa (DIANA), both of the Food and Agriculture Organization of the United Nations.

49. Remote sensing imagery from satellites is readily applied in the mapping of zones threatened by a wide range of hazards. This information helps to reduce risk by informing communities of the probability of certain hazards and of the need to include risk as a factor in making investment decisions. In this manner, for example, the human settlement of zones at risk of flooding may be reduced. Similarly, buildings to be located in known earthquake-prone zones may be constructed to standards that reduce structural damage caused by eventual earthquakes.

50. Data from meteorological satellites are of direct value to disaster management, for example in (a) monitoring severe storms of various kinds, (b) estimating heavy precipitation, both rain and snow, and (c) estimating tropical cyclone strength. The National Oceanic and Atmospheric Administration (NOAA) of the United States produces rainfall estimates from its geostationary satellite system every few hours for heavy precipitation events and for hurricanes that cross coastlines and continue overland. Additional data, such as soil wetness index, are used to assist in monitoring floods. The Advanced Very High Resolution Radiometer (AVHRR) is being used operationally for monitoring volcanic clouds that are hazardous to aircraft, as well as for monitoring extensive wildfires, such as those that occurred in Indonesia in 1997. The Total Ozone Mapping Spectrometer (TOMS), first launched aboard Nimbus-7, has also proved useful for monitoring explosive volcanic eruptions. Moreover, AVHRR, with spectral bands capable of measuring vegetative biomass, is also being used operationally for drought monitoring in the United States and elsewhere (e.g. the Famine Early Warning System (FEWS) in Africa and the National Agricultural Drought Assessment and Monitoring System (NADAMS) in India).

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*Space system for tracking ships in distress (COSPAS) of the Russian Federation and Search and Rescue Satellite-Aided Tracking System (SARSAT) of the United States.

51. The FEWS project is an example of the operational use of satellite technology in disaster management with clear benefits to the local population. The aim of FEWS is to reduce the incidence of famine in sub-Saharan Africa by monitoring the agricultural growing season. Monitoring is carried out through "greenness maps" derived every 10 days from AVHRR data. The maps allow analysts to monitor the development of vegetation in agricultural areas, comparing contemporary data with similar maps obtained continually since 1982. In addition, every 10 days, rainfall estimates derived from geostationary weather satellites are also compared with long-term averages. Additional information, such as *in situ* rainfall, field agricultural information and commodity price data, are taken into consideration in assessing famine risk using the FEWS approach.

52. Information on surface winds from the NSCAT microwave scatterometer (an instrument that was carried on board the Advanced Earth Observation Satellite (ADEOS) has significantly improved weather forecasting; 72-hour forecasts have been made with the same accuracy as was previously achieved 48 hours in advance. The recently launched Tropical Rainfall Measuring Mission (TRMM) is designed primarily to study the energetics of precipitation over tropical oceans. It is likely that techniques developed for TRMM for measuring rainfall will eventually be applied to the measurement of rainfall over land, thereby providing valuable information for disaster management applications such as flood and drought assessment. Analysis of European remote sensing satellite (ERS-1) scatterometer data over the Indian Ocean indicates a dramatic reversal in the wind direction over the west Arabian Sea three weeks in advance of the monsoon, followed by a large increase in wind velocity coinciding with the monsoon onset, a useful result relevant to the issuing of monsoon predictions.

3. Information exchange

53. Space-related technologies facilitate the communication and dissemination of information and thus play an important role in building public awareness of hazards and in subsequently reducing vulnerability. Among other things, these technologies make possible the broadcasting of appropriate radio and television programmes, as well as the use of computer networks for disaster management purposes (e.g. access to information on hazards or on persons affected by disasters). In addition, the technologies support basic telemedicine applications that can be of significant value during the emergency response phase of some disasters. The World Health Organization (WHO) is increasingly using mobile satellite communications in its field operations aimed at combating diseases or reducing health hazards.

III. INTERNATIONAL COOPERATION

A. Global and regional programmes and proposals

54. WMO coordinates the international World Weather Watch programme, through which national meteorological services can obtain information on meteorological hazards. Observations from land-based stations, aircraft, ships, buoys and geostationary and polar-orbiting meteorological satellites are exchanged worldwide through the Global Telecommunication System (GTS) of World Weather Watch. The data are received and analysed at various meteorological centres at the national, regional and global levels. The forecasts produced are disseminated through GTS and are used by national centres to support the issuance of warnings. Through World Weather Watch, national meteorological services are given technical guidance in a number of areas, including risk assessments, storm-surge modelling, flood-plain modelling and the design of defensive structures and measures (e.g. flood-protection works, windbreaks, shelter belts, building codes, and evacuation planning).

55. Among the current proposals for an international system for disaster management is the Global Disaster Observation System (GDOS), proposed by the Society of Japanese Aerospace Companies. GDOS would consist of a network of already existing and new satellites with capabilities of detecting and monitoring a variety of

natural hazards (e.g. wildfires, volcanic eruptions, typhoons and hurricanes) at appropriate spatial and temporal resolutions, on a continuing operational basis. Together, these satellites would, in the event of disasters, provide information on a near-real-time basis that would facilitate emergency response activities. They would also routinely acquire data needed for improving forecasting methodologies.

56. The United States has initiated a study of the feasibility of establishing a global disaster information network. With the broad participation of various key federal agencies, the initial stage of this network has been defined as encompassing the disaster-information communication needs of the United States. However, it has been agreed that, as the network becomes more firmly established in that country, it will be broadened to include similar international needs by involving other nations and the international community of disaster management practitioners.

57. It is generally acknowledged that telecommunications laws need to be modified in order to better meet the needs of disaster management. This recognition has led to the development of the draft convention on the provision of telecom resources for disaster mitigation and relief operations. The draft convention, which is expected to be adopted by States in 1998, would call for the removal or reduction of regulatory barriers to the use or transborder movement of telecommunications equipment, including satellite Earth stations, in disaster relief and related humanitarian applications.

58. A regional programme, Space Techniques for Major Risks Management (STRIM), is currently being developed by the Council of Europe, the European Commission, Centre national d'études spatiales (CNES) of France, and the European Space Agency (ESA). STRIM places emphasis on (a) training of staff concerned with risk management (e.g. civil protection organizations), (b) pilot projects, in cooperation with users, showing in concrete terms the advantages and the limitations of space technology for risk management, (c) exploitation of existing space-segment capabilities, and (d) recommendations for its future evolution.

59. The Committee on Earth Observation Satellites (CEOS) is in the process of defining internationally coordinated requirements for Earth observation capabilities through detailed studies in six project areas. One of the projects, led by the National Environmental Satellite, Data and Information Service (NESDIS) of NOAA, concerns the requirements for satellite (and ancillary) observations to support disaster management.

60. The secretariat of the International Decade for Natural Disorder Reduction, in conjunction with the United Nations Office for Project Services, the Economic Commission for Europe, the United Nations Development Programme, the United Nations Educational, Scientific and Cultural Organization (UNESCO), WHO and WMO, is working on initiatives related to early warning, the protection of industrial assets in countries with economies in transition, and the potential of public and private sector partnerships. One of the initiatives is the Leadership Coalition for Global Business Protection programme, which involves senior representatives of multinational corporations, selected major cities of the world, United Nations organizations, non-governmental organizations and international risk management officials. The initiative has been spearheaded by IBM Global Services in close collaboration with the secretariat of the Decade. Its aim is to engage corporate and public executives in sustained hazard assessment and risk management for the protection of common social and economic assets.

61. The Council of Europe, through its EUR-OPA programme, has sponsored the creation of an interactive database on space-related system providers, applications and solutions. The database is available to all disaster mitigation experts concerned with both natural and technological disasters and emergencies. Other databases with specific information on space techniques used in disaster mitigation exist on numerous World Wide Web sites in Japan, the United States and countries in Europe.

62. Several regional programmes or projects that depend on the use of space technologies for disaster management are already being planned. These include FUEGO, a project that will consist of a constellation of small satellites to be used for combating forest fires in the Mediterranean area. The Centre of Operational Services for the Mediterranean Environment (COSME) programme network will permit decision makers to access and exchange information and to benefit from services in order to resolve environmental problems. In this network, plans are being made to share data from high resolution satellite images using digital networks. A telecommunications satellite to cover needs in the Mediterranean area is also planned.

B. Education, training and technology transfer

63. Several international and regional organizations are involved in activities (e.g. seminars, workshops, courses, conferences, studies, technology-development programmes) aimed at the promotion of the use of satellites in disaster management, especially in developing countries. These include the Office for Outer Space Affairs, the Asia-Pacific Satellite Communications Council (APSCC), the American Institute of Aeronautics and Astronautics, the Centre for Space Science and Technology Education in Asia and the Pacific, the Confederation of European Aerospace Societies, the International Space University, the secretariat of the International Decade for Natural Disaster Reduction, UNESCO and WHO, as well as several space agencies and universities.

64. The Council of Europe, through its EUR-OPA Major Hazards Agreement, has co-sponsored with ESA a major study of disaster mitigation techniques, entitled "Study of space technology applications: identification of information and systems requirements for natural and technological disaster management". The study identifies, among other things, national approaches and concrete requirements for all major types of hazards. The Joint Research Centre in Italy supports a wide range of studies into the applications of space techniques to disaster mitigation.

IV. SOME SELECTED ISSUES OF INTEREST TO MEMBER STATES

A. Need for adequate infrastructure for information exchange

65. Despite the importance of adequate information exchange in all phases of disaster management, a number of Member States do not yet have the required telecommunications infrastructure that would support the reception and processing of disaster-related information, both nationally and internationally. Data from a variety of Earth observation, geo-positioning and communications satellites are useful for forecasting and tracking natural hazards, for educating the public and for subsequently issuing warnings of impending disasters. After a disaster has struck, communications are essential for maintaining links among disaster response officials, the government, affected populations, and sources of emergency relief supplies. Communications are crucial to the effective functioning of disaster prevention and relief organizations, whether private, national or international. Communications (among scientists, insurers, the media, the public, disaster response officials, and policy makers) are again crucial in studying hazards and in developing and implementing effective disaster prevention approaches. However, despite their value to development in general and to disaster management in particular, basic telecommunications services remain inadequate in some countries. In others, there is a need for disaster resistant forms of communications. It is therefore extremely important for countries to identify appropriate mechanisms that would lead to the acquisition of the necessary telecommunications infrastructure that they presently lack.

B. Need for higher national priorities for disaster management activities

66. Insufficient attention is being paid in a number of developing countries, particularly those in hazard-prone areas that have not recently experienced disasters, to implement appropriate disaster-management measures. Usually, only a small proportion of disaster-related expenditure is aimed at preventing or mitigating a disaster before it happens. Society as a whole (that is, individuals, the private sector, as well as governments) finds it difficult to justify expenditure in response to events that may happen, especially when confronted with many more immediate problems.

67. For disaster management to be truly effective, proactive measures need to be taken. Such measures include, for example, the establishment of early warning systems in all areas prone to hazards, pre-positioning of telecommunications equipment in strategic locations or areas known to be at risk, training and education on telecommunications technology for disaster management, and the enacting of legislation permitting the effective use of telecommunications equipment, including the transborder use of such equipment, during emergencies. Providing adequate financial support to education and training programmes (for example, in the use and interpretation of satellite imagery for disaster management) for civil protection managers and staff, as well as promoting awareness at the community level, is vital to reaping the maximum benefits from satellite systems.

68. A given type of natural hazard varies from one geographical region to another. It is therefore necessary for many countries to develop risk assessment methodologies and operational disaster management approaches that are adapted to the local risks. Identification of the national entity responsible for funding such research and development activity is often made difficult by the multiplicity of services at the national level whose mandates touch on disaster management. Enhanced coordination at the national level would better define user requirements and would ultimately increase the benefits that can be gained from space technology.

69. Although much research has been conducted on the applications of space technology to disaster management, the results have not been sufficiently integrated into operational activities. That would require better consultations at the national level among the various services concerned with disaster management, research organizations and the providers of space technology systems. The operational approaches to disaster management (including the techniques used for converting satellite data into information useful for disaster management) eventually adopted by each country would be of value to others. This information should therefore be shared with the international community.

C. International cooperation

70. At present, no mechanism exists to allow the disaster management community to have efficient and simple access to space assets, nor is there any clear articulation of the specific needs of the disaster management community that would enable owners of space assets to develop resources that cater for those needs. It has been suggested that, to facilitate a dialogue between users and service providers, an organization should be established. This body could, among other things, be responsible for (a) researching the needs of the disaster management community, (b) applying existing assets, and (c) suggesting new applications. The organization would allow for economies of scale and rationalization of the use of current space assets. If structured as a value-added service provider, such an organization could be a business that would market services to governmental and non-governmental disaster managers throughout the world.

71. The draft convention on the provision of telecom resources for disaster mitigation and relief operations (see paragraph 57 above) should be adopted by Member States. Humanitarian organizations are major users of mobile satellite telecommunications equipment. The rapid deployment of such equipment in the field during an emergency should not be compromised by the necessity of obtaining clearance for their importation by national authorities. Related issues are agreements for facilitating communications during disasters (e.g.

protocols for use, access priorities, allowed frequencies and favourable tariff structures for emergency communications).

72. International electronic networks that would facilitate information exchange within the disaster management community should be established. Such networks would be helpful in (a) the coordination of search-and-rescue teams from different countries, (b) the research of appropriate remote sensing and satellite communications technologies, (c) the assessment of the impact of disasters (e.g. damages and casualties), and (d) the evaluation of the types of disaster-related equipment and expertise available in countries and from international relief organizations.

73. Bilateral and multilateral development agencies should integrate into their decision-making processes the levels of risks posed by natural hazards. Projects that serve to reduce the risks of natural hazards should be given priority consideration from donor agencies for funding.

D. Access to satellites during emergencies

74. The portion of the total traffic of the world's telecommunications satellites that is used for natural disaster purposes is very small. However, the benefits that society gains from that use are significant. It is indispensable, therefore, to maintain emergency access to those satellites. Similar emergency access should also be ensured for data from geo-positioning and remote sensing satellites. The availability of satellite remote sensing data—often in near real time—is essential to its beneficial and effective usage in disaster management. It should be noted that near-real-time reception of data from satellite sources requires countries to have the appropriate telecommunications infrastructure (see paragraph 65 above). This issue is currently being considered in a CEOS pilot project on disaster management support.

E. Access to relevant information and techniques

75. While data and information derived from satellite observations can do much to assist in the important work of disaster management, they provide only a part of the total information needed for overall disaster management. Countries should therefore ensure that the non-space components of disaster management are adequately supported. Other information, relating to, for example, physical, cultural, and socio-economic conditions, must be available in order to derive useful information from satellite observations. Furthermore, such ancillary data should be made available in digital form in order to facilitate their rapid incorporation into GIS.

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MANAGEMENT OF EARTH RESOURCES

Background paper 3

The full list of the ackground papers:

1. The Earth and its environment in space
2. Disaster prediction, warning and mitigation
3. Management of Earth resources
4. Satellite navigation and location systems
5. Space communications and applications
6. Basic space science and micro gravity research and their benefits
7. Commercial aspects of space exploration including spin-off benefits
8. Information systems for research and applications
9. Small satellite missions
10. Education and training in space science and technology
11. Economic and societal benefits
12. Promotion of international cooperation

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CONTENTS

	Paragraphs	Page
PREFACE		3
SUMMARY		4
I. SATELLITE SYSTEMS FOR EARTH RESOURCES	1-9	4
A. Current major operational systems	4-6	5
B. New and future systems	7-9	6
II. REMOTE SENSING APPLICATIONS AND ASSOCIATED BENEFITS	10-48	10
A. Information needs	10-12	10
B. Distinctive advantages of satellite remote sensing	13-18	10
C. Applications	19-21	11
D. Benefits to society	22-48	13
III. INTERNATIONAL COOPERATION	49-54	18
A. Global environmental programmes	49-50	18
B. Education, training and technology transfer	51-52	18
C. International coordination of Earth observations	53	19
D. International data access	54	19
IV. SELECTED ISSUES OF INTEREST TO MEMBER STATES	55-64	19
A. Effective transfer of operational technologies	55-58	19
B. Data access	59-61	20
C. Development of operational remote sensing services	62-63	20
D. Local development of appropriate space programmes	64	21

Tables

1.	Major operational satellite systems routinely used for the management of Earth resources	6
2.	Principal specifications for the three major operational radar (microwave) satellite systems	6
3.	Satellite systems with capabilities potentially useful for the management of Earth resources, scheduled to be launched during the period 1997-2003 by government-supported agencies	7
4.	Recently launched and planned commercial satellite systems (sorted by launch date)	8
5.	Wavelengths in the electromagnetic spectrum routinely used for various remote sensing applications	12

PREFACE

The General Assembly, in its resolution 52/56, agreed that the Third United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE III) should be convened at the United Nations Office at Vienna from 19 to 30 July 1999 as a special session of the Committee on the Peaceful Uses of Outer Space, open to all Member States of the United Nations.

The primary objectives of the UNISPACE III Conference will be:

(a) To promote effective means of using space technology to assist in the solution of problems of regional or global significance;

(b) To strengthen the capabilities of Member States, in particular developing countries, to use the applications of space research for economic and cultural development.

Other objectives of the UNISPACE III Conference will be as follows:

(a) To provide developing countries with opportunities to define their needs for space applications for development purposes;

(b) To consider ways of expediting the use of space applications by Member States to promote sustainable development;

(c) To address the various issues related to education, training and technical assistance in space science and technology;

(d) To provide a valuable forum for a critical evaluation of space activities and to increase awareness among the general public regarding the benefits of space technology;

(e) To strengthen international cooperation in the development and use of space technology and applications.

As one of the preparatory activities for the Conference, the Office for Outer Space Affairs of the Secretariat has prepared a number of background papers to provide Member States participating in the Conference, as well as in the regional preparatory meetings, with information on the latest status and trends in the use of space-related technologies. The papers have been prepared on the basis of input provided by international organizations, space agencies and experts from all over the world. A set of 12 complementary background papers have been published and they complement each other and as such should be read collectively.

Member States, international organizations and space industries planning to attend UNISPACE III should consider the contents of the present paper, particularly in deciding on the composition of their delegation and in formulating contributions to the work of the Conference.

The Secretariat gratefully acknowledges the contributions that have been made by several specialists and organizations in the preparation and review of the present report, in particular: European Space Agency (ESA); Canadian Space Agency (CSA); National Aeronautics and Space Administration (NASA); National Oceanic and Atmospheric Administration (NOAA); Centre royal de télédétection spatiale, Morocco (CRTS); Indian Space Research Organization (ISRO); Manila Observatory, Philippines; National Institute of Aeronautics and Space (LAPAN), Indonesia; International Space University; World Meteorological Organization (WMO); Centre national d'études spatiales (CNES), France; Lawrence Fritz and Bruce Forster on behalf of the

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SUMMARY

The Earth's human population increases at the rate of more than 250,000 per day. This growth, which occurs mostly in developing countries, creates tremendous pressures to exploit existing resources to meet burgeoning social and economic development needs. The exploitation of resources has led to several significant environmental problems, notably large-scale deforestation, overfishing and destruction of fish habitats, land degradation and desertification, the spread of disease and pests, decreasing biodiversity, inadequate access to fresh water, ozone depletion and global warming. There is now a recognized need to manage the Earth's resources in a sustainable and environmentally sensitive manner. Remote sensing satellites provide a variety of information which is essential in facilitating such management.

Remote sensing technology confers many direct and indirect benefits on society, among which are: (a) cost and time savings, which are produced through achievement of greater efficiency and effectiveness in a wide range of planning, operational and monitoring activities, compared to alternative sources of comparable information, such as aerial photographic surveys; (b) greater savings in human lives through better supply of information useful in disaster management; (c) better quality of life through better food security and enhanced management of the environment and natural resources; and (d) greater reduction of uncertainty in general decision-making.

The number of operational satellites with sensors suitable for detailed mapping of Earth resources is increasing, owing in part to the advent of fully commercial satellite operations. The use of data from these satellites is also on the rise. However, most of the increased use is occurring in industrialized countries. Promotion of global development of the use of satellite remote sensing will require addressing a number of policy issues, including improved access to data and the creation of mechanisms and programmes that allow the greater use of satellite remote sensing in routine development activities.

I. SATELLITE SYSTEMS FOR EARTH RESOURCES

1. There is currently a wide range of satellite remote sensing systems that are useful for providing data to assist in the resolution of issues of national, regional and global significance. These systems range in spatial resolution from kilometres down to metres and record in wavelengths from the ultraviolet through the visible and infrared to the thermal infrared and microwave regions of the electromagnetic spectrum. The particular region over which a sensor acquires data, as well as its spatial resolution and revisit capability (i.e. the time between successive viewing by the satellite of a given site) are important considerations that determine the usefulness of the data for application in a number of key development sectors, such as agriculture, mineral exploration, forestry, hazards monitoring, fisheries and hydrology. Virtually all the satellite systems have comparable airborne equivalents; however, the airborne systems do not regularly acquire the data and can view only limited areas of the Earth's surface.

2. Civilian remote sensing from space began in April 1960 with the launch by the United States of America of the Television and Infrared Observational Satellite (TIROS-1) (a precursor of the Polar-orbiting Operational

Environmental Satellite (POES) series of satellites currently operated by the National Oceanic and Atmospheric Administration (NOAA)) as an experimental weather satellite. This polar orbiting satellite produced the first TV-like pictures of the world's surface in a systematic and repetitive manner. The United States military launched its first Earth observation satellite, Discoverer, in August 1960. During the 1960s a series of remote sensing satellites was launched for weather, intelligence and lunar landing programmes by the United States and the Union of Soviet Socialist Republics. In 1972 the first civilian satellite that was designed specifically to collect data of the Earth's surface and resources was the Earth Resources Technology Satellite (ERTS-1), which was later renamed Land Remote Sensing Satellite 1 (LANDSAT-1). Subsequent satellites in the series LANDSAT-2, -3, -4 and -5 were launched in 1975, 1978, 1982 and 1984, respectively.

3. From 1972 until 1986, satellite remote sensing imagery was available to the general public only from the LANDSAT series of satellites. Since then, however, the options available to data users have steadily increased. Several other Earth resources satellite systems of differing technical characteristics (that is, instrument payload, orbital details, and primary application areas) have been launched and operated by different space agencies with the support of national Governments. The number of possible sources of remote sensing information continues to increase. Systems that can record at very high spatial and spectral resolutions and that will have very short revisit capabilities will be available in the near future. This will assure users of increasing flexibility in obtaining needed information in a timely manner. A synopsis of the current operational systems is presented in the following paragraphs. This is followed by an outline of some of the new systems that will be launched in the near future (i.e. from the beginning of 1998, the date of writing of this report, onwards).

A. Current major operational systems

4. At present, six systems provide most of the current data for Earth resource management on a regular basis. These systems, and the dates of first launch, are: the Advanced Very High Resolution Radiometer (AVHRR) of NOAA of the United States; LANDSAT, 1972; Système pour l'observation de la Terre (SPOT), 1986; Indian Remote Sensing Satellite (IRS), 1988; Earth Resources Satellite (ERS), 1991; Japanese Earth Resource Satellite (JERS), 1992; and RADARSAT, 1995.

5. The NOAA-AVHRR system was designed to provide information for hydrological, oceanographic and meteorologic studies, although the data have also been used for land monitoring applications. There are a series of these systems in Earth orbit, and each has a twice daily return period (night and day). The LANDSAT systems were the first to be designed to provide global coverage of the Earth's surface on a regular basis. Two multi-spectral remote sensing instruments of different spatial and spectral resolutions are carried by the current LANDSAT systems. These are the Multi Spectral Scanner (MSS) and the Thematic Mapper (TM) sensors. The SPOT systems 1, 2 and 3 were launched in 1986, 1990 and 1993, respectively. These identical systems can acquire data in panchromatic and multispectral modes. The SPOT systems have a standard repeat cycle of 26 days, but because of a side viewing capacity they can revisit a site at more frequent intervals (up to every 2 days) and also have the capacity to create a stereoscopic pair of images. The IRS satellite systems (1A, 1B, 1C and 1D) were launched in 1988, 1991, 1996 and 1997, respectively. They have a return period of 22 days. The IRS-1C and -1D have both panchromatic and multispectral sensor. Sensor characteristics for these four satellite systems are summarized in table 1.

6. RADARSAT, JERS-1 and ERS-1 and ERS-2 carry radar or microwave remote sensing systems. These are active sensors having their own source of energy, so that data can be acquired at any time, night or day, depending on the satellite's position above the Earth's surface. ERS-1 and ERS-2 were launched in 1991 and 1995, respectively. JERS-1 was launched in 1992 and RADARSAT in 1995. Both ERS and JERS have other sensing instruments in addition to their imaging radar instruments, and RADARSAT has a number of imaging modes at different ground resolution. Additional technical characteristics of these three systems are presented in table 2.

Table 1. Major operational satellite systems routinely used for the management of Earth resources

System	*Characteristics*	*Spatial resolution*
NOAA (AVHRR)	VNIR(2) TIR(3)	1.1 km
LANDSAT	VNIR(4)	56 m * 79 m
	VNIR SWIR(6)	30 m
	TIR(1)	120 m
SPOT	PAN	10 m
	VNIR(3)	20 m
IRS	PAN	5.8 m
	VNIR(3)	23.5 m
	MIR(1)	70 m

Note: VNIR—visible to near-infrared; SWIR—short-wave infrared; PAN—panchromatic; MIR—middle infrared; TIR—thermal infrared. The number enclosed in brackets ( ) refers to the number of spectral bands.

Table 2. Principal specifications for the three major operational radar (microwave) satellite systems

	ERS-1 & 2	*JERS-1*	*RADARSAT-1*
Wavelength	5.7 cm	23.5 cm	5.7 cm
Frequency	5.3 GHz	1.28 GHz	5.3 GHz
Polarization	VV	HH	HH
Incidence angle	23 degrees	35 degrees	20-49 degrees
Swath width	100 km	75 km	100 km 500 km [SM]
Range resolution	30 metres	18 metres	25 metres [SM]
Azimuth resolution	30 metres	18 metres	28 metres [SM]

Note: SM—in standard mode.

B. New and future systems

7. The remote sensing systems that have been developed with the support of national Governments have focused on the collection of broad scale, medium and low resolution data more appropriate for such information as climate research, environmental monitoring and resource management. However, the new systems that are planned or have recently been launched by current and new commercial operators (tables 3 and 4) show a clear trend towards higher spatial and spectral resolution[1] (see also background paper 9 (A/CONF.184/BP/9) on Small satellite missions, some of which are related to remote sensing). In the year 2000, if all current plans for Earth viewing satellites are fulfilled, there would be 31 satellites in orbit at the same time that would be capable of providing data of 30 metres or better resolution. The highest spatial resolution of the systems planned is 0.8 m.

As many of these systems will also have a stereoscopic facility, they will be able to provide high-resolution digital terrain models, with equivalent contour intervals of the order of 2 metres. The high spatial resolution offered by these systems will also allow three-dimensional modelling of buildings and the mapping of land use, as opposed to land cover. The main market for the data from many of the high-resolution satellites includes precision crop management, mapping and diverse Geographic Information System (GIS) applications (e.g. those related to public utilities, urban planning, forestry and disaster management). Vendors claim that the products from the commercial systems will generally be available within a few hours of satellite data acquisition. Such availability will depend, however, on users' access to adequate information-technology facilities that would allow near real-time transfer of data.

8. The next generation of Earth observation satellites will monitor atmospheric structure and chemistry, the oceans, the land surface and vegetation in unprecedented detail and accuracy. These observations will contribute to the comprehensive assessment of the state of the Earth system and identify the nature and cause of natural and human induced changes in the global system.

9. With the increasing availability of a wide spectrum of satellite data to choose from, the concept of data fusion will also become more widely recognized. Rather than using data from one system, at one resolution, from one date, which may not satisfy all the information needs of the user, multiple data sets will be integrated. Software programs for optimizing the extraction of information for specific applications will become available.

Table 3. Satellite systems with capabilities potentially useful for the management of Earth resources, scheduled to be launched during the period 1997-2003 by government-supported agencies

System	*Characteristic*	*Spatial resolution*
CBERS (1999, 2000)	VNIR(4)	20 m, 260 m
	PAN	20 m, 80 m
	SWIR	80 m
	TIR	160 m
RADARSAT-II (2000)	SAR(C)	3 m, 9 m, 25 m, 50 m, 100 m
Envisat-1 (1999)	VNIR(15)	250 m, 1 km
	SAR(C)	30 m, 100 m
SPOT-4 (1998)	VNIR SWIR(4)	10 m, 20 m
SPOT-5A (2002)	VNIR SWIR(4)	10 m
	PAN	5 m
IRS-1D (1997)	VNIR(4)	23.6 m
	PAN	5.8 m
	SWIR	70.8 m
	WiFS	188 m
IRS-P5 (1999-2000)	PAN	2.5 m
IRS-P6 (2000-2001)	VNIR(4)	23 m
	VNIR(3)	6 m
	AWiFS(3)	80-100 m

System	*Characteristic*	*Spatial resolution*
ALOS (2003)	VNIR PAN SAR(L)	10 m 2.5 m
KOMPSAT (1999)	VNIR	10 m
Resource-01 N4 (1998)	VNIR(3)	25 m
Resource-F2M (1998)	VNIR(4)	6-9 m, photography
NIKA-Kuban (2000)	VNIR(1) VNIR(9)	2-4 m, photography 3-5 m, 6-8 m, photography
SICH-1M (1999)	VNIR	45 m
LANDSAT-7 (1998)	VNIR/SWIR(6) TIR PAN	30 m 60 m 15 m, 5 m, 10 m
EOS-AM1 (1998)	VNIR(3) SWIR(6) TIR(5)	1 m 30 m 90 m
EO-1 (1999)-Exp	VNIR/SWIR(9) PAN H	30 m 10 m
LightSAR (2000)	SAR(L)	
TOPSAT (2001)	SAR(L)	

Note: Exp—experimental mission; SWIR—short-wave infrared; VNIR—visible to near-infrared; PAN—panchromatic; SAR(X)—X-band synthetic aperture radar; H—hyperspectral sensor. The number enclosed in brackets ( ) refers to the number of spectral bands.

Launch dates are subject to change. Only missions with at least one major sensor yielding a spatial resolution better than 100 m are mentioned.

Table 4. Recently launched and planned commercial satellite systems

Mission	*Sensor characteristics*	*Special resolution*	*Launch*
Israel Aircraft Industries (IAI)	PAN	1.3 m	-
Orbview-3 (ORBIMAGE)	PAN VNIR(4) H	1 m, 2 m 4 m 8 m	1999
IKONOS-1 (Space Imaging EOSAT)	PAN VNIR(4)	1 m 4 m	1998

Mission	*Sensor characteristics*[a]	*Special resolution*	*Launch*
IKONOS-2 (Space Imaging EOSAT)	PAN VNIR(4)	1 m 4 m	1998
Quick Bird (Earth Watch)	PAN VNIR(4)	1 m, 2 m 4 m	1998
GDE Systems	PAN	0.8 m	1998
West Indian Space (EROS-A)			1998
Resource 21	VNIR(4) SWIR	10 m 20 m, 100 m	1999
ARIES-1	VNIR(32) SWIR(32)	30 m 30 m	2000
EROS-B1 (West Indian Space)			1999
EROS-B2, B3 (West Indian Space)			2000
GEROS I, II (GER Corporation)			2000
GDE Systems			2000
GIBSAT (Kodak)			2000
Resource 21-A, -B (Resource 21)			2000
EROS-B4, -B5 (West Indian Space)			2001
XSTAR A (Matra-Marconi)			2001
OrbView-3B (ORBIMAGE)			2001
GEROS-III, IV (GER Corporation)			2001
Resource 21-C, -D (Resource 21)			2001
EROS-B6 (West Indian Space)			2002
XSTAR-B (Matra-Marconi)			2002
GEROS-V, VI (GER Corporation)			2002
EROS-B6 (West Indian Space)			2003

Note: Exp—experimental mission; SWIR—short-wave infrared; VNIR—visible to near-infrared; PAN—panchromatic; SAR(X)—X-band synthetic aperture radar; H—hyperspectral sensor. The number enclosed in brackets ( ) refers to the number of spectral bands.

[a]Where available, sensor characteristics are shown.

II. REMOTE SENSING APPLICATIONS AND ASSOCIATED BENEFITS

A. Information needs

10. The world's population, currently estimated at approximately 6 billion, is rapidly increasing at a rate of more than 250,000 per day, with much of this growth taking place in developing countries. This growth has placed considerable strain on available resources and has contributed to a number of major environmental problems. Redressing these problems requires better management of the Earth's resources and its environment based on adequate knowledge of the state of the Earth's land and water surface and its atmosphere. Information from satellite remote sensing can contribute significantly to the acquisition of this knowledge and thus to better management of the limited resources.

11. While remote sensing makes a significant contribution to fulfilling information needs, it should be recognized that satellite remote sensing plays a complementary role to other means of spatial data acquisition. Other data sources, including existing maps, aerial photos, reports, statistical data, historical information and interviews with land holders, should form part of an overall data gathering process. Data collected in the field, from aircraft or from spacecraft, ultimately, are only of benefit if they can assist in the solution of an information need, at a cost appropriate to the user, be it an individual, an institution, a country or an international organization. By understanding its advantages and disadvantages, one is able to develop strategies in which remote sensing contributes notably to the cost-effectiveness of data collection.

12. Among the major information needs for many developing countries are those required to support decision making in several important sectors. These sectors are typically: (a) natural resources (including, agriculture, forestry, mineral, water, and fisheries); (b) the environment; (c) human resources (including education and health services); (d) prevention and mitigation of natural disasters and conflicts; and (e) crime prevention. Successful remote sensing applications have been developed in each of these development sectors, and they confer a number of direct and indirect benefits to society.

B. Distinctive advantages of satellite remote sensing

13. Satellite remote sensing offers several unique advantages over alternate means of data collection, such as airborne and ground surveys, which makes it an ideal tool for fulfilling certain information needs. The advantages generally relate to:

(a) The lower cost of imagery acquisition;

(b) The speed and relative ease with which space-borne imagery could be obtained;

(c) The high frequency of data collection, resulting in current, i.e. up-to-date, information;

(d) The homogeneity of data collection by the use of a single instrument to capture data over large areas;

(e) Improved data coverage, particularly in remote areas and for large regions;

(f) The spatial continuity of observations.

14. The advantages of remote sensing satellites are valid not only for geographically large (e.g. country-wide) areas of interest, as has historically been the case, but also for small areas of several square kilometres, as evidenced by the recent advent of high-resolution commercial remote sensing satellites. These commercial systems are targeted specifically at users requiring information over relatively small areas, for which data

acquisition, especially multiple acquisitions, would not be cost-effective using aircraft owing to large fixed costs for undertaking airborne missions. For comparison, it is estimated that, in North America, a satellite ortho-image map derived from 2-m resolution imagery would cost, on average, one half to one third of that derived from aerial photography. In China, a comparative study of aerial survey and satellite remote sensing for mapping an area of 608,000 hectares revealed that the use of satellite remote sensing yielded savings of 55 and 66 per cent in acquisition and labour costs, respectively. In India, the cost for carrying out integrated resources mapping using the satellite remote sensing as opposed to conventional (air photo based) methods results in average savings of 52 per cent. Examples from the agriculture sector in the United Kingdom show cost-benefit ratios of 1:10 by using satellite remote sensing data in operational monitoring programmes.

15. Many of the non-commercial satellite systems routinely acquire imagery of large regions of the Earth. The archived data represent a valuable source of consistent information that permit retrospective (time-series) studies, such as determining the origin of marine pollution or the rate of depletion of a specific resource. Satellite image archives can now be readily consulted from remote locations, thanks to the growth of information systems and the Internet, thereby improving access to users throughout the world. Examples of relevant World Wide Web sites include the following: Centre for Earth Observation (www.ceo.org); Committee on Earth Observation Satellites (ceos.esrin.esa.it/dossier/); Satellite Active Archive (www.saa.noaa.gov); and European Space Research Institute (http://shark1.esrin.esa.it/informations.html).

16. The digital format of imagery and the synoptic coverage of remote sensing satellites facilitates processing of the imagery into products meeting a variety of needs. Imagery relating to a range of sizes (e.g. a site, a standard map sheet, a state or a whole country) could easily be extracted or created using mosaics. This characteristic allows, for example, the elaboration of value-added GIS-ready products meeting the specific needs of various groups of users from the same set of source images. This encourages economies of scale and competitive pricing and further enhances the cost-effectiveness of satellite data acquisition.

17. It is now widely recognized that many environmental problems are global in scope and cross international boundaries. Decisions for redressing these problems cannot therefore be made in isolation. Satellite remote sensing systems represent the only source of data that can provide an all-encompassing, integrated view that is consistent with the scale of the problems.

18. Operational remote sensing has today evolved to the stage where an end-user could, with comparative ease and at short notice, obtain new or archived imagery of any desired geographic area, within a relatively short period ranging from a few hours to a few weeks. On the other hand, aerial surveys of comparable areas may require several months for implementation.

C. Applications

19. With the wide range of sources of remotely sensed image data, at varying wavelengths and spatial resolutions, the applications of Earth observation systems for natural resources management are varied, as indicated by the following list:

(a) Agriculture, e.g. disease detection, water needs assessment;

(b) Fire and hazards detection and tracking;

(c) Disaster monitoring and relief;

(d) Environmental monitoring, particularly oil spills and pollution;

(e) Coastal resource management and engineering;

(f) Land information, and other urban and regional planning products;

(g) Navigation safety;

(h) Topographic mapping at large scales;

(i) Hydrologic monitoring of urban and other catchment areas;

(j) Placement of facilities, e.g. roads, pipes, power lines and other infrastructure;

(k) Census, tax and property evaluation;

(l) Tourism and recreation;

(m) Business and marketing, including market research and demographics;

(n) Law enforcement, peacekeeping and treaty monitoring.

20. The usefulness of data from Earth observation systems is directly related to the spectral bands used for acquisition. Table 5 lists the wavelengths that are routinely used for the remote sensing of a range of Earth resources, including those that are of particular interest to developing countries such as coastal and freshwater, forestry and agricultural resources. A comparison of these wavelengths with the spectral bands of the sensors on the various existing and planned satellite systems listed in tables 1 to 4 can be used to gauge the usefulness of the satellite systems for a given application. Other considerations include the spatial resolution of the image as well as the frequency with which images can be acquired.

Table 5. Wavelengths in the electromagnetic spectrum routinely used for various remote sensing applications

Wavelength range	*Application related areas*
0.40-0.50 µm (blue)	Water penetration and water depth
0.50-0.60 µm (green)	Vegetation greenness, ocean colour
0.60-0.70 µm (red)	Chlorophyll absorption in healthy plants, iron oxide content in soils, water sediment load
0.70-0.90 µm (near IR)	Healthy vegetation response, crop monitoring and classification, land water separation, vegetation and soil separation, separation of built and vegetated surface cover
1.55-1.75 µm (near IR)	Soil moisture content
2.00-2.40 µm (SWIR)	Presence of clay-based minerals
3.00-4.00 µm (mid IR + thermal IR)	Volcanic activity, bush fires, underground fires
9.00-12.50 µm (far IR + thermal IR)	Earth ocean and land temperatures
2.4-3.75 cm (X-band microwave)	Forest canopy shape, crop classification. Ocean roughness, wind speed
3.75-7.5 cm (C-band microwave)	Crown thickness, leaf/branch size and orientation. Plant morphology. Ocean surface roughness, wind speed; oil seeps; surface elevation; land cover; bathymetry; geology; gravity fields; sea-ice and iceberg monitoring
15-30 cm (L-band microwave)	Trunk size and tree density; ocean roughness; soil surface roughness; soil moisture content; forest clearcut areas
30-100 cm (P-band microwave)	Trunk size and tree density; soil moisture content; soil surface penetration and under surface phenomena; snow penetration

21. From a technical operational standpoint, the successful application of remote sensing will depend on several factors including: (a) an understanding of the relative spectral responses of the materials being sensed; (b) an appropriate choice of spectral, spatial and temporal resolutions of the remotely sensed data to be used, taking into consideration the characteristics of the features or phenomenon of interest and the scale of presentation; (c) the acquisition of images at the most opportune time or times when the features of interest are most easily differentiated and therefore amenable to detection; and (d) the use of appropriate interpretation methodologies, including the use of visual and digital approaches and the use of data integration/modelling techniques using GIS.

D. Benefits to society

22. Society benefits considerably from the use of satellite remote sensing. Several examples of beneficial applications are presented in this section. Emphasis is placed on applications whose technical and economic feasibility depend largely on the inherent advantages of satellite remote sensing over alternative means of data collection. Indeed, for certain applications, owing to constraints of time, geographical coverage, costs or the essential characteristics of the parameters measured, satellites provide the only feasible means of data collection. Applications can generally be categorized into one of the following classes: mapping, monitoring, modelling and measuring. Societal benefits are presented following this categorization.

Mapping

23. Appropriate maps are a necessity for a wide range of planning and development activities. However, in developing regions and even in some industrialized countries, such maps are scarce or outdated, owing partly to the high cost of preparing them using traditional approaches. The increasing availability of satellite remote sensing imagery is modifying the way in which maps are currently prepared and subsequently used. Rather than manually extracting thematic data from air photos and presenting these as maps, the imagery itself is ortho-rectified, annotated and used as maps. Such maps provide more information content and are more readily understood by a wider variety of end-users, of differing levels of formal education. They are being used increasingly as an effective, unfiltered tool for communication between various parties in natural resource and environmental projects, particularly those where rural communities in developing countries are involved. The high positional accuracy of ortho-rectified maps derived from high-resolution remote sensing satellites makes these maps a cost-effective alternative to field surveys, especially in remote and inaccessible areas in which ground surveying or aerial surveying could prove very difficult.

24. Land reform is being undertaken in a number of countries throughout the world, including those where economies are in transition to a free-market system. Private ownership of land is a major driving factor in national economies and a significant factor in sustainable development. The need to respond rapidly to the huge demand for land titles at affordable costs is being fulfilled through the use of novel, inexpensive approaches to cadastral mapping involving the use of high-resolution satellite imagery and land-based surveys.

25. The wide perspective of satellite images has allowed geologists to map quite readily subtle regional geological features (such as faults, lineaments, geomorphological or lithological contacts), which would not otherwise be easily observed from the ground, owing to lack of surface expression, but which can be recognized on small-scale imagery. The mapping of such features facilitates the exploration for minerals as well as for groundwater, both of which are often key target resources for development.

26. Topographic data, a frequent input in many planning and engineering studies, can be derived from either stereo optical or radar images. Digital elevation models are generated from satellite radar imagery using interferometry or radargrammetry techniques. The high precision of these models allows their use in monitoring hazards that are preceded by ground movements, such as volcanoes, earthquakes and landslides.

27. In regions of the world where almost permanent cloud cover prevents the acquisition of conventional optical satellite images, radar imagery is being used to create updated maps at a 1:200,000 scale with acceptable levels of positional accuracy. This has been achieved using block triangulation and precision orbital data, without the need for local ground surveys.

28. In agriculture, remote sensing (from optical as well as radar satellites) is used to supplement conventional sources of information in determining agricultural statistics at the national as well as regional levels. Low to high spatial resolution optical imagery from a number of dates during the growing season as well as radar imagery are used in the identification of crops. Radar imagery is particularly useful in areas such as the humid tropics and northern Europe, where frequent cloud cover may obscure the land surface. Satellite imagery in conjunction with limited ground sampling is routinely used to identify and measure crop area as well as areas of arable land in countries comprising the European Union under its common agricultural policy programme. This activity is undertaken to support the administration of area-based subsidies to farmers. Some 3 million crop declarations are made each year, and their accuracy needs to be checked before the crops are harvested. Approximately 5 per cent of the individual declarations are systematically checked using information from either satellite remote sensing or aerial photography, or both in combination. Similar programmes for measuring areas under cultivation and predicting crop yields exist in several other countries, such as China, India, Morocco and Senegal.

29. Maps developed from satellite remote sensing are used to support sustainable development. In India, for example, satellite-derived maps of natural resources, in conjunction with collateral data on socio-economic, cultural, demographic and meteorological aspects, are used to map unique land units for which specific sustainable development plans (e.g. allowable land use practices and conservation measures) are elaborated.

30. Some agricultural activities have a significant impact on the concentration of greenhouse gases and contribute to global warming. Satellite remote sensing is playing an invaluable role in mapping wet-land rice fields and consequently determining the extent to which they are contributing methane gases to the atmosphere.

Monitoring

31. The frequency of overhead passes of a satellite over a given location combined with the capability of many sensors to view off-nadir positions facilitate a variety of monitoring activities over land as well as sea. Targets of interest are usually phenomena or features that change over time.

32. A key factor in sustainable development is knowledge of the rate at which an existing resource is being depleted so that appropriate management strategies can be formulated. The frequent coverage of remote sensing satellites facilitates this goal by providing time-series information on a variety of important resources including vegetation (forests, rangelands), soils and surface water sources. In forestry, for example, remote sensing information facilitates the monitoring of areas of deforestation, afforestation, biomass volume, disease, insect infestations and forest fires. Such monitoring allows Governments to assess quickly the impact of various policies and institute changes, as necessary. Satellite images of many regions of the world dating back to 1972 (or earlier, in the case of images gathered for military intelligence purposes) exist in the archives of the various satellite operators or related agencies. These data represent a consistent and valuable resource for studies requiring the analysis of widespread regional changes over time, e.g., deforestation, coastal erosion and lake level variations.

33. Sea surface temperature and colour have been correlated with zones where fish productivity is highest. Ocean colour information is regularly used to track marine areas where phytoplankton-rich waters or relatively cold "upwellings" occur. This information is transmitted in near real-time to fishing fleets for exploitation, thereby increasing their profitability. Unfortunately, many local fishing boats in developing

countries are not large enough or suitably equipped to take advantage of this capability. Historical ocean-colour information also allows identification of regions that are at high risk of degradation owing to pollution and that therefore require protection. Remote sensing data are also useful for identifying algal blooms and coastal fishing grounds that are threatened by pollution from land-based sources or by destruction of spawning grounds, e.g. wetlands. Routine acquisition of satellite imagery of areas of the world that are at risk owing to high levels of marine traffic are helpful in detecting pollution plumes and in analysing their trajectories. The data are also useful for evaluating the impact of pollution on the marine as well as near-shore environments. In some countries, such as Indonesia, satellite remote sensing data are being routinely used for monitoring the growth of coral reefs as well as for assessing marine fish stocks.

34. During emergencies, such as earthquakes, hurricanes and extensive floods, the ready availability of up-to-date imagery allows emergency response agencies to know the areas of greatest damage and need, thereby permitting the planning and subsequent implementation of effective relief measures. This information is also used by insurance companies to settle claims for damages caused to homes or to crops rapidly. In the case of weather-related disasters, satellite meteorology is used to develop a better understanding of weather systems leading to improved disaster warnings. Satellite remote sensing facilitates the regular monitoring of the extents of annual floods, and the mapping of zones at risk to floods, as well as the formulation of appropriate measures for reducing vulnerability to flood hazards. Usually, ground-based synoptic observation networks for monitoring the weather are inadequate, generally owing to a low density of observation points. Space-based platforms, on the other hand, provide wide spatial coverage over land as well as marine areas and are not limited by factors that normally hinder access by ground-based surveys.

35. Inexpensive ground stations for receiving weather information from polar-orbiting and geostationary satellites are now affordable by most developing countries. In some developing countries, the imagery has allowed the identification of areas that will be affected by cyclones and facilitated the issuing of warning messages. In this manner, remote sensing has helped to save many lives by providing warnings and allowing the timely evacuation of people and livestock. Warnings issued sufficiently in advance allow other specific remedial measures such as the recall of fishing boats to harbour, the advanced harvesting of crops and the protection of reservoirs. Other benefits from satellite meteorological observations include improved aviation safety and efficiency and better detection of dust storms and sandstorms, as well as of volcanic ash plumes.

36. Monitoring of crops on individual farms using high-resolution imagery helps to identify areas that are under stress owing to lack of water, are in need of fertilizers or are affected by diseases, long before the plants begin to show visible evidence. This facilitates the optimal distribution of water, thereby enabling savings as well as improving crop yields. It also avoids the excessive application of fertilizer with its potentially deleterious effects on the environment.

37. Ready access to Earth observations is already creating new opportunities for greater social and political openness among countries. Government officials can legally purchase information that can contribute to timely decisions leading to greater security. Examples are information relating to major environmental trends in neighbouring countries or disputed territories. The remote sensing information serves as an impartial medium for discussing potentially contentious issues.

Modelling (forecasting)

38. Most satellite remote sensing data are readily available in digital format. Numerous classification algorithms have been developed to transform the digital data automatically into useful thematic information. This transformation simplifies the incorporation of remotely sensed information into GIS. GIS are now in widespread use, not only as a database for the storage and retrieval of spatial information but also as an interactive management tool for analysing alternative strategies for resource allocation. GIS software now

supports a variety of modelling approaches for forecasting outcomes based on the information provided in a spatial database. For certain applications, the spatial database may consist of time-series information derived mainly from remote sensing satellites.

39. Multi-date satellite imagery (both optical and radar) of crops at different phenological stages is used in conjunction with other information, such as meteorological and soil data, to develop models for forecasting production several weeks before harvesting. This application can be of considerable value in developing countries that lack reliable agricultural surveys. Forecasts are useful in setting prices, providing vital inputs for crop insurance and making timely arrangements for the storage, importation, exportation and efficient local distribution of agricultural produce. Low production forecasts (e.g. as a result of drought conditions) would allow time for appropriate remedial measures to be implemented. Such is the basis for programs such as the famine early warning system (FEWS) being applied to a number of developing countries in Africa.

40. Data furnished by regular monitoring of sea surface temperature and elevation by Earth observation satellites are used to forecast the onset of the El Niño phenomenon in the Pacific Ocean. This phenomenon is associated with abnormal weather conditions in America, Asia and Africa. El Niño forecasts are beneficial in that potentially adverse impacts on human activities, such as reduced agricultural production, can be anticipated.

41. Remote sensing data in combination with other information in GIS are used to analyse the associations, in time as well as in space, between the patterns of landscape elements that are critical to disease transmission and the spatial distribution of infectious diseases, both emerging and re-emerging. These analyses allow the development of remotely sensed predictors of disease risk that can be applied to larger regions where field data are unavailable. Examples of some recent applications include the identification of high anopheline mosquito-producing rice fields in California; the prediction of the abundance of mosquitoes in several villages in Chiapas, Mexico; the measurement of the exposure to risk to Lyme disease in the United States; and studies of cholera in Bangladesh, Leishmaniasis in Brazil, vector-borne diseases in south-eastern Turkey, and equine encephalitis in Venezuela.

42. Satellite imagery showing the areal extents of snow are used as input to hydrological models to predict run-off from snow melt. This allows better irrigation management of cultivated areas located downstream of catchment areas.

43. Historical wave and wind information collected by ERS satellites are being used in sea state forecasting and "hindcasting" applications. Hindcasting is used to confirm ocean and weather conditions at particular locations and at specific times. The information obtained is used by insurance companies in conducting risk analysis and in settling claims. Radar satellites also permit improved sea-ice and iceberg monitoring for offshore activities and ship routing in polar regions. Databases containing historical observations of sea-ice conditions permit the establishment of design parameters for ships and offshore platforms and the selection of optimum shipping routes.

44. A rising demand worldwide for potable (drinking) water owing to increasing population and generally higher levels of water use has heightened the need for water resources assessment and management. Remote sensing satellites provide data on several key hydrological variables (e.g. rainfall, soil moisture, evaporation and snowfall) at a scale that is appropriate for this assessment. Satellite systems that are useful for water resources assessment include polar-orbiting (e.g. NOAA series, the Tropical Rainfall Measuring Mission (TRMM)) and geostationary (e.g. METEOSAT, GMS, GOES) primarily meteorological satellites. In addition, radar satellite systems (see table 2), from which information on soil moisture can be obtained, and optical systems (see table 3), which yield information useful for run-off and hydrological modelling, are

indispensable for proper assessment. This satellite-based approach to water resources assessment is especially important in regions of the world where adequate hydro-climatological networks do not exist.

45. The forecasting of droughts is greatly assisted by information on past and current drought conditions. Droughts tend to affect large areas at a time, and monitoring should be carried out at an appropriate scale. Generally it is not necessary to monitor droughts at high spatial resolution, but it is important to observe their impact on a regular basis. An appropriate system to monitor droughts is NOAA-AVHRR, which has the appropriate spectral bands and the capacity to monitor vast areas on a daily basis. The onset of drought conditions in a given year can be predicted by comparative analysis of the trend in satellite-derived vegetation indices for that year relative to the trend in a normal year. This warning capability has allowed authorities in some developing countries, where annual rainfall is highly variable, to mitigate the effects of droughts through an appropriate redistribution of food supplies for humans and fodder for livestock. The Food and Agriculture Organization of the United Nations (FAO) "Artemis" early-warning system for Africa, is based on this capability and involves the use of vegetation indices and cloud-cover duration parameters, both of which are derived from remote sensing satellites. The cost of reception and use of NOAA data is low. Thus, for some developing countries, this application may well represent a low-cost means of developing local expertise in the use of Earth observation systems for resource management.

Measuring (detection)

46. The multi-spectral nature of most satellite images allows the identification and discrimination of a wide variety of surface features as a consequence of their distinctive responses over different regions of the electromagnetic spectrum (ranging usually from the visible to near-infrared, short-wave infrared, middle infrared, thermal infrared and microwave regions). This capability is responsible for the detection of various targets of interest in natural resource management, such as water bodies, wetlands, oil spills, algal blooms, discharges of heated water from power plants, geological alteration products that are indicative of mineralization, iron oxides that are responsible for acid run-off from mines, tree diseases and zones of salinization in agricultural fields. Airborne surveys could also be used in these applications; however, the costs of collecting data of comparable quality would be considerably higher.

47. Airborne sensors with a far larger number of spectral bands than the maximum currently available seven bands on a space-borne platform (LANDSAT 5) have been developed for some time now. However, the radiometric resolution of sensors on board satellites is improving. The EO-1 spacecraft, scheduled for launch in 1999 (see table 3), will carry two experimental sensors having 233 and 309 narrow spectral bands covering the 0.4-2.5 micrometer spectral range and a spatial resolution of 30 m. The ill-fated Lewis spacecraft, launched in August 1997, carried a hyperspectral sensor with a capability to acquire images over 384 bands. Hyperspectral imagery would allow, for example, not only the detection but also the estimation of the magnitude and cause of vegetation stress in an agricultural crop. Stress can be due to a variety of factors, including insufficient or excess fertilizer or inadequate water.

48. In addition to increased radiometric resolution, sensors of increasingly greater dynamic range are being developed. This permits greater contrast enhancement and hence better capability to derive information from imaged areas, especially if these are acquired under low-light conditions. At least one proposed commercial system will have a dynamic range of 11-bits (2048 levels) as opposed to the 8-bits (256 levels) of most of today's Earth resource satellites.

III. INTERNATIONAL COOPERATION

A. Global environmental programmes

49. There is now a general heightened awareness of the global influence of human actions on the habitability of the Earth and the need to enact appropriate measures to address complex, interlinked global problems related to human activity. The problems of greatest concern highlight the need to manage the Earth's resources and environment in a sustainable manner. These problems relate, among others, to: (a) stratospheric ozone depletion; (b) deforestation; (c) destruction of fisheries; (d) land degradation and desertification; (e) spread of disease and pests; (f) decreasing biodiversity; (g) inadequate access to fresh water; and (h) global warming of the Earth arising from the use of fossil fuels with its attendant problems (e.g. rises in pollution and sea level, increased evaporation and changing patterns of precipitation leading to increased risks of flooding and droughts).

50. Several international agreements, monitoring and research programmes, as well as global observing systems relating to the global environment, now exist. The agreements include, for example, the Montreal Protocol on Substances that Deplete the Ozone Layer, concluded at Montreal on 16 September 1987, the Rio Declaration on Environment and Development, 1992,[2] the Convention on Biological Diversity, 1992,[3] the Non-Legally Binding Authoritative Statement of Principles for a Global Consensus on the Management, Conservation and Sustainable Development of All Types of Forests, 1992,[4] the United Nations Framework Convention on Climate Change, 1994 (A/AC.237/18 (Part II)/Add.1 and Corr.1, annex I) and the United Nations Convention to Combat Desertification in those Countries Experiencing Serious Drought and/or Desertification, particularly in Africa, 1994 (A/49/84/Add.2, annex, appendix II). International monitoring and research programmes include the Earth Science Enterprise (ESE), the International Geosphere-Biosphere Programme (IGBP), the World Climate Research Programme (WCRP), DIVERSITAS and the International Human Dimensions Programme on Global Environmental Change (IHDP) and focus on diverse aspects of the global environment. The acquisition of remotely sensed information is critical to the successful execution of these programmes. Three global observation systems, comprising both ground-based and remote measurements, that facilitate the collection and sharing of global data sets have recently been developed: the Global Climate Observing System (GCOS) initiated the United Nations Environment Programme (UNEP), the Intergovernmental Oceanographic Commission of the United Nations Educational, Scientific and Cultural Organization (IOC/UNESCO), the World Meteorological Organization (WMO) and the International Council of Scientific Unions (ICSU); the Global Ocean Observing System (GOOS) being developed by UNEP, IOC/UNESCO, WMO and ICSU; and the Global Terrestrial Observing System (GTOS) developed by UNEP, FAO, UNESCO, WMO and ICSU.[5]

B. Education, training and technology transfer

51. Several countries have bilateral arrangements that provide limited training, education and technology transfer opportunities for developing countries in satellite remote sensing technology. Education and training opportunities in the form of fellowships, workshops, conferences, expert meetings and short training courses are also regularly provided to participants from developing countries by various space agencies, professional scientific societies, universities (including the International Space University), regional commissions of the United Nations, as well as by the Office for Outer Space Affairs through its Programme on Space Applications. This Programme is financially supported by Member States, which host the events, and by various co-sponsors including government-aided and private-sector organizations involved in space-related activities.

52. Several regional centres for space science and technology education are being established throughout the developing world with the aid of the Office for Outer Space Affairs. The first of these centres, established

in India in 1996, serves countries in Asia and the Pacific. Efforts are under way to establish similar regional centres in Africa, Latin America, eastern Europe and western Asia. Apart from the fostering of South-South cooperation, these centres contribute to the building of local expertise and ultimately to the success of technology-transfer programmes.

C. International coordination of Earth observations

53. In light of the increasing number of satellites and the need to fulfil the information needs of end-users, improved coordination of Earth observation satellites has become necessary. The Integrated Global Observing Strategy (IGOS) initiative being developed by the Committee on Earth Observation Satellites (CEOS) specifically aims at providing an integrating framework for space-based and ground-based observations needed to support the requirements of international global observing systems (e.g. GCOS, GOOS, GTOS), as well as global and regional research programmes.

D. International data access

54. Adequate access to the data needed to tackle global environmental problems is a necessity for the global scientific community. Several international programmes have established Internet-based information systems that allow users throughout the world to gain access to data. These systems now include the Earth Observing System—Data and Information System (EOS—DIS), the Global Land Information System (GLIS), the European Earth Observation System (EEOS), the Earth Observation Data and Information System (EOIS), the Global Environmental Information Locator Service (GELOS) and the International Directory Network of CEOS (CEOS—IDN). National space and remote sensing agencies are developing their own interoperable networks (e.g. CEONet in Canada) to provide access to domestic and international data from several sources. Effective access to these information systems is dependent on having adequate telecommunications links to the Internet.

IV. SELECTED ISSUES OF INTEREST TO MEMBER STATES

A. Effective transfer of operational technologies

55. There are a number of obstacles to the use of data from Earth observation systems, particularly in developing countries. These are the cost of data purchase, the cost of data acquisition facilities, the cost of data-processing facilities, the limited number of appropriately trained staff at the technician, professional, project management and research level, the lack of knowledge of potential users and the inflexibility of existing resource managers. As a consequence, only a few developing countries are currently making optimum use of data from Earth observation systems. It is considered that the lack of appropriate mechanisms for technology transfer is a major factor limiting the use of these data. While there are many instances of equipment, sensors and image analysis systems being directly transferred, the transfer concept must also include the concept of absorption of the technology on the part of the receiving country.

56. For technology transfer to be effective, education and training are required at a number of levels to produce the full spectrum of activities ranging from research to technical support. While the number of staff required for research is relatively small compared to technician-level support, the need for developing countries to develop a local, autonomous basic research capability rapidly cannot be over-emphasized. Such a capability promotes creative thinking and enhances the indigenous ability to adapt, modify and create new techniques that contribute to national development. For optimum research development it may be appropriate to consider the establishment of focal research centres, attached to universities where a "threshold

concentration" of scientists and technologists can operate in a catalytic manner to maximize the return of research and development expenditure.

57. To date, little effort has been directed by countries at determining their human resources needs and the required educational programmes they need to develop. Education and training have been piecemeal, undertaken as part of a variety of projects sponsored by various aid, bank, bilateral or multilateral agencies. In the main this training has been directed to the professional class, usually with emphasis on specific applications. Without research or technical support, the transferred technology eventually wilts, and these well-trained professional staff seek alternative career paths or leave the country.

58. Equipment for the transfer of expertise in the various applications of remote sensing technology are no longer expensive. However, successful transfer cannot take place without adequate funds. Because of this, many developing countries have had to rely on a range of bilateral and multilateral sources for funding and other support. However, the activities generated by these groups are in the main uncoordinated, leading to many cases of inefficient overlap of similar projects and programmes. In addition, and importantly, areas targeted by these agencies do not necessarily cover the full remote sensing needs of the country or may have low priority. Thus, while international funding is desirable and indeed necessary, much greater effort by each country should be directed to determining their own specific needs and to better coordinating activities through national committees. Each country must assess its funding requirements and determine the merits of each funding opportunity on the basis of national needs. Great care should be taken with funding proposals that impose specific equipment and methodologies on the user country. In the long term, these may lead to costly maintenance, restriction of opportunities and inappropriate technology transfer.

B. Data access

59. It is critical to the development of indigenous capabilities in remote sensing that countries have access to data from Earth observation systems. While this can be achieved through the establishment of a national receiving facility and an appropriate data distribution mechanism, such a facility may not be affordable or even appropriate for all countries. Of far greater importance to many countries are the ways in which they can cost-effectively access the data that they need.

60. The advent of fully commercial remote sensing data providers augurs well for the increased availability of data that would meet a wide range of needs. However, users in some developing countries are unlikely to afford commercial rates.

61. The data policies of government-supported remote sensing systems vary considerably. Key opposing factors that influence pricing policies are the affordability of the data on the one hand and the sustainability of Earth observation programmes on the other. Making the data available freely or at a low cost is only sustainable with continuous government funding. Leaving the availability entirely to market-driven forces or providing data at the true cost would exclude users with low budgets. Other pricing schemes, such as a two-tiered system or pricing based on the value of the information derived from the Earth observation data, have been proposed. The ideal solution appears to be one in which there are high-volume sales at low unit prices. This would provide cheap data for users as well as high revenues for data suppliers, thereby allowing them to continue their Earth observation programmes. The policies and mechanisms for progressively attaining this objective need to be developed.

C. Development of operational remote sensing services

62. While there has been significant growth in the volume of Earth observation data, there has not been a comparable growth in the applications of the data, particularly in the operational and commercial domains.

Even industrialized countries have found it necessary to set up national programmes to stimulate the development of applications. The exploitation of space is therefore not only a function of technical capability to process data and to produce a product. At present, most of the activities in Earth observations are limited to the development of technical capabilities to acquire and process Earth observation data and the carrying out of demonstration studies. However, to be effective, the promotion of space technology must involve greater investments in the subsequent stages of application development, namely, the implementation of pilot services, followed by pre-operational services that are adjusted to meet user requirements and, finally, continuous operational services that are fully integrated into the user environment.

63. A primary challenge in ensuring greater use of remote sensing information is the development of new ways to use available data more effectively and for a wider set of applications. This will require the development of new software for analysis, visualization and display. It will also require a renewed effort to provide training for communities of potential data users.

D. Local development of appropriate space programmes

64. Many barriers to the greater use of remote sensing information exist in some developing countries, and appropriate mechanisms must be found for overcoming them. Some of the activities that would contribute to the local development of space programmes and that present opportunities for international cooperation are: (a) the building of local awareness of space technology and its benefits; (b) the strengthening of training and technology transfer programmes, including the sharing of experiences among developing countries; (c) the development of appropriate national regulatory frameworks and policies in space-related matters; (d) the development of the local private remote sensing sector; (e) the establishment of national points of contact for promoting remote sensing in a manner consistent with real needs; (f) the promotion of remote sensing in academic institutions and the provision of more opportunities for both short- and long-term training and education;* and (g) the recognition by Governments of space technologies as a priority measure for meeting national development needs.

Notes

[1]Spatial resolutions are classified as follows: very low >300 m; low >30 <300 m; medium >3 <30 m; high >0.5 <3 m; very high <0.5 m.

[2]*Report of the United Nations Conference on Environment and Development, Rio de Janeiro, 3-14 June 1992* (United Nations publication, Sales No. E.93.I.8 and corrigenda), vol. I: *Resolutions Adopted by the Conference*, resolution I, annex I.

[3]See United Nations Environment programme, *Convention on Biological Diversity* (Environmental Law and Institutions Programme Activity Centre), June 1992.

[4]*Report of the United Nations Conference on Environment and Development* ..., annex III.

[5]See also background paper 1 on the Earth and its environment in space (A/CONF.184/BP/1).

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*The benefits that a country can reap from satellite remote sensing can roughly be gauged from the number of professionals engaged in mapping and surveying activities. A comparison shows that mapping professionals in developing countries are under represented, often by a factor greater than 7, relative to their numbers in industrialized countries of equal size and population density.